ASSESSING THE ECOLOGICAL SIGNIFICANCE OF THE MEKONG TRIBUTARIES

VOLUME 1 - MAIN REPORT

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Summary

This paper considers the ecological and fisheries significance of the tributaries of the Mekong. It is one of a series commissioned by the Mekong River Commission considering significance studies on the hydrology, navigation, hydropower, and social aspects.

At the outset in developing this paper, it was realized that there has generally been very little systematic or basin-wide work done on the Mekong and much of the ecological parameters that have been studied have been done on the Mekong mainstream, not the tributaries. It is therefore very difficult to make comparisons of the tributaries based upon patchy and incomplete data, which have been collected over the years using a variety of different methods. This realization has guided the development of the study in the use of basin-wide geographic and other data sets, generally held by the MRC, and to make extensive use of GIS analysis to develop proxy indicators of ecological and fisheries significance.

One hundred and four catchments make up the Lower Mekong river basin. These have been analysed using datasets on the physical character of the area – elevation, slope, stream order, stream length leading to stream density; on the climate – mean annual rainfall and temperatures of the catchments; on the geology and soils – especially limestone (with presence of karst and caves) and fluvisols (to represent floodplain areas); on land use to get an idea of forest, paddy and other agricultural areas; and on human populations to get population densities, urban and rural. Composite datasets on the ecological zones through which the tributaries pass have been derived from work done earlier by WWF. With all these data sets extensive analysis of the character of each tributary, usually the percentage make-up of the parameters within each catchment, or length of the tributary, and the percentage contribution of the tributary to the Mekong as a whole. The tables with all of this data has been compiled in Volume 2 – Data Analysis, which contains the data for each parameter by tributary, its source and an analysis of significance by identifying the 80th, 50th and 20th percentiles.

Volume 1 presents the synthesis of these analyses. In order to do this the 104 tributaries have been divided into three groups – the 27 large tributaries (over 5000 sq km catchment), the 50 medium tributaries (1000 – 5000 sq km) and the 27 small tributaries (under 1000 sq km). A further sub-grouping has been based on geophysical area of the Mekong basin – Northern Highlands, Khorat Plateau, Annamites, Kontum Massif, Tonle Sap basin and Cardamon mountains and the Delta. This approach has allowed a more manageable assessment. It is important to realize that the data has been used with little ground truthing, surveys or visits to check out the reality of the ecological character of the tributaries apart from the authors' general knowledge of the basin.

For the biological aspects, most of the assessment has been based upon fish. Fish species lists for 22 tributaries have been used to generate a predictive model for fish communities, comparing the most likely fish species to be found in rivers that have similar physical, geological and ecological characteristics. The fish species lists have been analysed in terms of the fish guild make up, the presence of endemic, native and introduced species, and the presence of endangered species as identified by the

IUCN Redlist. The Redlist has also been used to identify tributaries that contain other endangered aquatic species. Other indicators of biodiversity importance includes Protected Areas, Key Biodiversity Areas, wetlands and the presence of important wetland sites in each catchment.

No estimates have been found for the primary productivity of the rivers and so estimates of the relative productivity of each tributary have been made based upon the potential yield of fish. This has been estimated in two ways, both of which have limitations, but which can be used for relative comparisons. One estimate is based upon the consumption of fish by the people living within 5 km of the rivers and using recognized consumption figures to get to a potential fisheries yield of the tributary. The second way has been to estimate the surface area of the water of the river and estimate the potential yield using recognized fish production figures per hectare. This measures the potential yield of the resident fish populations (but not migratory fish) and is expressed as a kilograms per kilometre per year.

The degree of modification of the tributaries is also an important ecological factor, and this has been estimated from the density of human populations, the changes in landuse, and infrastructure such as road density, irrigation and hydropower. The MRC databases on landuse, irrigation and hydropower have been applied to each catchment for this purpose.

In analyzing the ecological significance of the 104 tributaries of the Mekong, it is clear that it is impossible to give a single answer because ecological significance also begs the question of significance for what purpose. In order to rationalize this further each size grouping of tributaries has been reviewed for four different aspects – ecological diversity, ecological uniqueness, ecosystem productivity and the degrees of modification. The following paragraphs summarise the significance findings of the study in these four different aspects.

Ecological diversity

- **Large tributaries –** for the greatest ecological diversity amongst the tributaries that have high elevation ranges and slopes, the Nam Ngum, Se Kong and Stung Baribo stand out. For the tributaries that do not have high elevations or wide elevation ranges, the Nam Chi, the Sre Pok and the Delta stand out. The tributaries with the highest proportion of migratory fish and highest biodiversity interest come lower down the Mekong and include the Se San, Stung Sen, Stung Pursat and Prek Chhlong.
- **Medium tributaries –** Of the rivers with the greatest slopes, elevations and elevation ranges, especially in the Northern Highlands, the Nam Nuao, Nam Tam, Nam Nhiep and Nam Sane stand out. All of these have high forested areas. Nam Mae Kham has the highest proportion of migratory fish and Nam Phuong has high fish species diversity. The medium tributaries on the Khorat Plateau have high proportions of natural wetlands. Nam Heung stands out for its wide elevation range and high ecological diversity. In the Annamites the Se Bang Nouan stands out. Of the tributaries flowing into the Tonle Sap, the Stung Battambang and Stung Sangker stand out. The 4P rivers (Prek Preah, P. Krieng, P. Kamp and P. Te) also appear to be ecologically diverse.

- **Small tributaries –** in the Northern Highlands, the Nam Ngam and Nam Thong have higher physical diversity. The Huai Bang Lieng from the Bolevan, and Prek Mun flowing into the Mekong near Siphandone both are ecologically diverse, as are the small rivers from the eastern edge of the Khorat Plateau – H. Bang Haak and H. Muk.

Ecological uniqueness

- **Large tributaries –** In the Northern Highlands the Nam Ou stands out for its ecological uniqueness. Nam Mae Kok and Nam Mae Ing on the right bank of the Mekong appear to be very different from the left bank rivers. The large rivers with the highest proportion of limestone in the catchment are Nam Suong, Nam Khan, Nam Cadinh and Se Bang Fai, followed by the Nam Ou and Nam Tha – most of these also have karst and cave structures. Nam Songkhram, Nam Chi and Nam Mun stand out on the Khorat Plateau as tributaries with limited elevation range, high proportions of natural wetlands, high fish species diversity and presence of endangered species. Se Kong, Se San and Sre Pok have important wetlands, high fish species diversity, although they are more ecologically diverse. Siem Bok is ecologically unique because it does not have a major tributary in the catchment, but scores highly on its ecological function linking the Mekong with Tonle Sap through overland flows, and other indicators of biodiversity richness. The Delta is an ecologically unique catchment.
- **Medium tributaries –** In the northern Highlands most of the medium tributaries have wider physical ranges, apart from the Nam Sang and Nam Mi. The medium tributaries with the highest limestone in the catchment are Nam Sang, Nam Phuong, Nam Houng, Nam Phoul and Nam Sang and Nam Hinboun in the Annamites. Nam Sing, Nam Sang and Nam Hinboun are also restricted to a single ecological zone. The tributaries in the Northern Highlands with the highest fish endemicity are the Nam Nuao, Nam Pho, Nam Ngaou and Nam Beng. Again the right bank river, the Nam Mae Kok stands out as different. On the Khorat Plateau, many medium tributaries are associated with high proportions of wetlands and important wetland sites including H. Bang Bot, Huai Mong and Nam Kam, whilst those restricted to a single ecological zone are H. Nam Som, Nam Suai, H. Bang Sai and H. Bang I. The H. Nam Huai, Nam Loei and H. Bang Koi have high fish diversity indices. Lower down the Mekong the Huai Tomo, Tonle Repon and O Talas stand out for ecological uniqueness. The Tonle Sap itself is a unique ecosystem together with its feeder streams St Chikreng, St Siem Reap, St Battambang and St Dauntri.
- **Small tributaries –** Many small tributaries are limited to single ecological zones including B. Khai San, Doi Luang Pae Muang, Muang Liep and Nam Phone, Huaag Hua and H. Kok. Ones that stand out are Nam Nhah and the limestone rich tributaries of B. Nam Song and Nam Mang Ngai. The small tributaries with high fish diversity indices include Nam Keung, Phu Luong Yot Huai and H. Ma Hiao. The Khorat small tributaries have predicted high numbers of endangered fish species, but none have recorded presences of other endangered aquatic species.

Ecosystem productivity

- **Large tributaries –** The tributaries further south in the LMB have higher fish productivity. Nam Mun, Nam Chi and the Delta stand out as having the highest fish productivity of the large tributaries followed by the rivers flowing into the Tonle Sap – St Sreng, St Sen, St Mongkol Borey, St Chinit, St Baribo and also Prek Thnot. Of the more northern rivers, the Nam Ngum and Nam Songkhram are important, as are Se bang Hieng, Sre Pok and Siem Bok. For the percentage of black and migratory fish the tributaries that stand out are St Sen, Siem Bok, St Baribo, Prek Chhlong and Prek Thnot. However, the tributaries that have a higher importance of migratory over blackfish are the higher and more northerly rivers including the Nam Ou, Nam Mae Kok, Nam Suong, Nam Khan, and the Se Bang Fai and the 3S rivers.

- **Medium tributaries –** The rivers with the greatest productivity are the Tonle sap and its influent rivers – St Chikreng, St Siem Reap, St Staung, St Sangker and St Dauntri. Further north the Huai Luang and Nam Kam have high fish estimates based on consumption and the Nam Suai and Se Bang Nouan have high estimates based on surface area, but there is no linkage with areas of natural wetland. Nam Mae Kok again stands out for having high proportions of black and migratory fish, but black fish become more important further south in Nam Phuong, Huai Som Pak and Huai Tomo above Khone Falls and in St Battambang, St Dauntri, Prek Kamp and Prek Te. The tributaries in the north have high migratory to black fish ratios apart from the Nam Mae Kok.
- **Small tributaries –** None of the small tributaries have high estimates for fish production apart from the Ban Khai San. The small tributaries that have medium estimates for fish production based on surface area are Doi Luang Pae Muang, Nam Thon, Hoaag Hua, Huai Muk and Prek Mun.

Degree of ecosystem modification

- **Large tributaries –** The least modified large tributaries lie in the north of the LMB as measured by indices apart from hydropower development. The ones with least hydropower development capacity lie in the south of the basin. Those with the highest forest areas and lowest landuse change include the Nam Tha, Nam Cadinh and Se Kong, but both the last two have high hydropower development. The least modified appear to be Nam Tha, Nam Suong and Stung Sreng. Nam Ou stands out for its low population density, low land use modification, road and irrigation development but high urban population percentage and high hydropower. Nam Chi and Nam Mun stand out as highly modified because they have a number of high modification indices, but no low modification indices. Se Done has only high urban percentage, but is otherwise only moderately modified. Se San and Sre Pok have high urban populations, hydropower and infrastructure index but a low landuse change index. Further south many of the tributaries have high road development, low hydropower capacity and of these Siem Bok, Prek Chhlong and the Delta also have high irrigation and infrastructure indices. The Delta is one of the catchments with the greatest modification. St Chinit, St Pursat, St Baribo appear to be among the least modified, though St Baribo has high population densities and urban populations.
- **Medium tributaries –** The medium tributaries are least modified in the north, especially in the Northern Highlands. An exception is Nam Mae Kham which has high urban populations and urban areas and greatest landuse modification, Nam Beng and Nam Ngeun have high

infrastructure index and high hydropower capacity, as does Nam Sane and Nam Mang. There is a grouping of catchments in the north of north east Thailand with high populations, urban percentages and areas, high paddy areas and landuse modification. These inlcude H. Luang, H. Mong, Nam Suai while Nam Loei has high landuse modification. H. Bang Bot and H.Nam Huai on the Khorat Plateau also have high modification indices. Nam Kam is highly modified by high population density, paddy areas, irrigation and infrastructure index. Of the Tonle Sap tributaries many have high infrastructure indices, but St Siem Reap and St Dauntri stand out because of high population density, high paddy areas and high road development.

- **Small tributaries –** There is a clear pattern that the small tributaries in the Northern Highlands are least modified, except for Nam Ngam and H. Ma Hiao which have high population density, urban areas and infrastructure index. These have centres of population in a small catchement area. Similarly further south Nam Kadun, Hoaag Hua and Nam Mang Ngai have high population desnity, road development and irrigation development. There are heavily modified small tributaries on the Khorat Plateau including Phu Pa Huak, H. Khok, H. Thuai, H. Ho, H. Bang Hak and H. Muk. The least modified small tributaries are the Nam Thon in the Annamites and H. Bang Lieng from the Bolevan and Prek Mun.

In addition to this systematic analysis of the tributaries of the Mekong, a complementary study has been carried out on the changes in the current and future connectivity and degree of regulation of the Mekong by hydropower. Using a model based on ecosystem connectivity, this study has shown that currently the the entire Mekong basin has a Dendritic Connectivity Index (DCI) of 44.4% and a River Ecosystem Connectivity Index of 73.4%. If by 2022 the planned additional 84 dams are built, the DCI will decrease to 9.7% and the RECI will decrease to 5.1%. The hydrological Degree of Regulation (DOR) will double from a current 4.4% in the Mekong Delta to 9.8%, whilst the overall network DOR (netDOR) will increase from 1.99% to 5.45%.

1 Introduction

The Mekong River Basin is experiencing a critical stage of development. Water resources development is accelerating, in particular in the hydropower sector. The accelerating development needs to be complemented by effective governance and management of water and related resources to ensure that further development of water-related resources is sensitive to the maintenance of vital ecosystems and capture fisheries productivity, on which most of the poor population depend for their livelihoods.

Given the progress of preparatory works for proposed hydropower projects on the mainstream and on significant tributaries, urgent action is required to provide a consistent framework for the appraisal of individual projects.

The 'Draft Scoping Report, A Multivariate Approach to Defining 'Significance' in Regard to the Tributaries of the Mekong River System' presented at the 29th MRC Joint Committee in March 2009 focused on water resources related developments on tributaries. The Report built on an earlier preliminary study and further developed the concept of a multivariate analysis showing how 'significance' may be evaluated in terms of hydrology as well as other criteria, including water-quality, aquatic ecosystems, and fisheries. The Report also proposed a methodology allowing for a consistent assessment of cumulative impacts based on the topology and connectivity of the entire river network. The present author has used this significance paper very effectively in a Cumulative Impact Assessment of hydropower development on the Nam Ou, showing that it is one of the most significant tributaries for many different criteria.

However, this draft scoping report did not go into the detail of the criteria, and a series of further studies have been commissioned by the MRC, which expand and improve the approach and methods used and provide further insights into the significance of the tributaries.

This paper considers the aquatic and terrestrial ecosystems in the watersheds and the importance of the fish biodiversity and productivity. With the limited time available for this study, the focus has been upon identifying suitable indicators of significance and developing an appropriate methodology, rather than providing a complete assessment of all the tributaries. It should also be noted that the main tributaries themselves are made up of smaller rivers at lower stream orders. It is intended that the methods proposed can also be used to assess the ecological importance of these lower order streams, in order to guide conservation and protection strategies and measures.

2 Literature reviews

In order to develop the approach to be suggested for the assessing the aquatic and terrestrial ecosystem and fisheries significance of the Mekong tributaries, an enquiry was sent out to various organisations and people who were known to have had ideas and experience of assessing riverine ecosystems and fisheries, especially in the Mekong region. The responses from these enquiries yielded very fruitful leads to the literature, and ideas. The people and organisations who have helped in this way are listed in the acknowledgements. In addition a web-based search of the work of various conservation organisations and publications provided further insights.

The starting point of this literature review is the draft Scoping report by the MRC (MRC, March 2009). The indicators used in this scoping report that will contribute to an assessment of ecological significance include:

- Stream Order using the Strahler method,
- Hydrological indicators, such as mean annual flow, mean wet season flow, mean dry season flow
- Sediment load
- Water quality
- Aquatic health – based on biomonitoring criteria
- Aquatic ecology – based on lifecycle of fish – important spawning grounds, important nursery/feeding grounds, migration corridor
- Aquatic ecology – biodiversity – endemic or threatened species, high fish biodiversity
- Aquatic ecology – protected areas in the catchment
- Fisheries yield (measured by consumption)
- Land use – natural land cover and agricultural production

To a large extent this study is an amplification or closer definition of these broad indicators. This leaves only two criteria as being less important indicators – hydropower potential and navigation. These are covered under other significance papers contributing to the series. However, hydropower is important as an indicator of disturbance and block of connectivity of the tributary. An attempt will be made in this study to assess the loss of tributary connectivity by both hydropower and irrigation schemes already in existence and planned (obtainable from the MRC hydropower and irrigation databases).

2.1 Aquatic ecology

2.1.1 Hydrological indicators

During the Integrated Basin Flow Management (IBFM) studies on the Mekong, Adamson and King drafted a paper that starts to identify key environmental flow indicators that define both the morphology and ecology of the tributaries. (Adamson, Draft). This paper identified four hydro-biological seasons measured by six hydrological parameters, namely:

1. Dry/Low flow season, indicated by
    a. Minimum flow and date
    b. Mean daily dry season discharge

c. Coefficient of variation of dry season daily flows

2. Transition period 1 between low flows and high flows (on the Mekong usually for a few weeks in May/June), indicated by Number and magnitude of pre-flood season spates or freshlets
3. Flood/High flow season as indicated by whether the peak and volume of water passing falls above or below mean flows.
4. Transition period 2 between wet season and dry season, generally a brief one to two weeks during mid-November, as indicated by the average daily rate of flow recession (cumecs/day)

The work generated some original thinking in the definition of flow parameters for the Mekong . The metrics used to define the start and end of the four flow seasons were (Adamson P. , December 2006):

Season	Start	End
Dry season	Average daily flow recession (decrease) is 1% or less over 15 consecutive days, indicative of base flow conditions	Twice the minimum daily discharges for the current dry season occurs, indicating that discharges have increased significantly and the low flow season is at an end
Transition season 1	End of dry season	Start of flood season
Flood season	Daily discharges exceeds mean annual discharge for the first time	Last date upon which daily discharge falls below the mean annual discharge
Transition season 2	End of flood season	Start of dry season

The papers describe the application of some of these indices to different locations on the Mekong mainstream. They have not been applied to the tributaries, though this may be considered under the separate hydrological significance paper (Adamson pers.com). The paper indicates that given the predictability of the monsoon in the Mekong region, there is a very narrow range of seasonal onset and end dates, and very little variation between the patterns of flows at Vientiane and Kratie. It may be that though there is a very large difference between low and high flows in the Mekong, the actual differences between the tributaries may be very small and not significant as ecological indicators. However, the extent of changes in these indicators in the tributaries as a result of upstream regulation (hydropower and irrigation) will show the level of disturbance away from natural conditions.

2.1.2 Terrestrial and Aquatic ecology

Far more studies have been done upon the terrestrial ecology of the Lower Mekong than of the aquatic ecology, which is very patchy. There is an assumption that the terrestrial ecology is an important indicator of aquatic ecology, and this has been translated into the definition of aquatic ecological zones lead by WWF Greater Mekong. These ecological zones form a very important cornerstone of this study and are described below.

An indicator of terrestrial biodiversity importance has been the designation of Protected Areas and identification by conservation organisations of Key Biodiversity Areas. An indicator of aquatic biodiversity importance is the designation of Ramsar site and the identification of important wetland sites by the MRC.

2.1.3 Fish and aquatic biodiversity

The main studies on the aquatic biodiversity of the Mekong tend to be focused on fish. Fish species lists for the different tributaries have been compiled and consolidated from a variety of different sources by Eric Baran with additional information especially on the Tonle Sap tributaries from Ashley Halls.

Studies on other aquatic biodiversity are very sparse and not comprehensive for many of the tributaries. However, in early 2011, the IUCN Aquatic Biodiversity specialist group undertook a systematic review of the information on four taxa – aquatic plants, fish, molluscs, and dragon flies to complement earlier global amphibian reviews. They came up with an updated Red List assessment for the aquatic biodiversity of the Mekong and this has been used extensively for assessing the species found in the tributaries

2.2 Data bases

The following databases and maps have been accessed from the MRC and other organisations to carry out this assessment.

- MRCS (2000) Watershed Classification Project (WSCP)
- Mekong mainstream and tributary rivers and streams, with stream order, showing 7 levels
- Digital Terrain Model (DTM) for the Lower Mekong Basin for altitudes of tributaries and for determining slopes of the tributaries between each node
- Lower Mekong Basin 1968 ATLAS: Geology
- Lower Mekong Basin 1968 ATLAS: Land Potential
- Soil Map of the Lower Mekong Basin
- Landcover of the Mekong basin 1992/93 and 2003
- Wetlands of the Mekong basin
- Forest Functions / Protected Areas of the Lower Mekong Basin for Protected areas, Ramsar sites

An Assessment of Water Quality in the Lower Mekong Basin (Technical Paper No. 19, 2008)

Diagnostic study of water quality in the Lower Mekong Basin (Technical Paper No. 15, 2007)

3 Development of indicators

3.1 Principles

In developing the indicators to be used for assessing the significance of the Mekong tributaries, there are several principles which have been adopted:

- The indicator should be fairly simple and understandable
- The links and relevance of the indicator should be clearly explainable
- The indicator should be straightforward to apply e.g. through GIS analysis, without detailed modeling or computations
- Where possible, it should be based upon existing data sets, or partial data sets of the tributaries
- It is recognized that data for many of the tributaries is not available e.g. for biodiversity apart from fish, and a series of surrogate indicators of diversity need to be developed based upon easily measurable physical features e.g. geology, hydrology, geomorphology, and habitat diversity

3.2 Parameters selected and analysed

The approach that has been taken has been to use the different GIS datasets available through the MRC and other sources to develop statistics about the 104 tributaries of the Lower Mekong Basin and their catchments which contribute to the ecological parameters. These have been presented in the tables in Volume 2 – Data Analysis.

The ecological significance of these different parameters has been arranged in three main groups –

- Physical, geological and hydrological characteristics - those factors that define the geomorphology of the river and its habitats
- Biological characteristics – the biological components, especially ecological zones and connectivity, rare and endangered species and fisheries.
- Factors affecting the ecology of the tributaries and their catchments including land use, human populations, roads, irrigation and hydropower.

The significance of the different tributaries for each of these parameters has been assessed by comparing the percentage that the tributary makes to the total found in the Lower Mekong Basin and the percentage of the total within catchment. Thus an analysis is carried out comparing the contribution that the tributary makes to the overall LMB, and the proportion within the tributary and its own catchment. The 80th percentile is considered as highly significant, the 50th percentile as significant, the 20th percentile as moderately significant and the rest as least significant.

Maps have been prepared showing these degrees of significance through different colour shading of the catchments, and these are also shown in Volume 2.

3.2.1 Physical, geological and hydrological characteristics of tributaries

3.2.1.1 Catchment size

The catchment size of the tributaries provides the main grouping for analysis. Catchment size is principal determinant of the flows in the tributary, although there will be some variation dependent upon the rainfall and run-off. For the purposes of this analysis, the tributaries have been grouped into three size groupings –

- *Large = > 5,000 sq km,*
- *Medium = 1,000 – 5,000 sq km and*
- *Small = < 1,000 sq km*.

This is similar to the percentile groupings indicated in Volume 2, but these ones are chosen to fit with the other significance studies. All subsequent analysis is done comparing tributaries within these size groups. The tributaries in the different size groups are shown in Table 4-2.

3.2.1.2 Stream order, length and number

The order, length and number of the different streams that make up each tributary are an indication of the complexity of the catchment. Whilst catchment size and length of all the stream orders are to some extent similar measures, the ecological diversity is more a reflection of the stream order, length and number.

3.2.1.3 Elevation and slope

The ecological diversity of rivers often depends upon the elevations at which they rise at, and where they discharge into the Mekong. The greater the elevation ranges, the greater the probability of ecological diversity. The measures here include the length of each stream order in the different elevation ranges, below 100 m, 100 – 500 m, 500 – 1000 m, 1000 – 1500 m and above 1500 m.

The slope of the first and second order tributaries is a reflection of the basin topography, with higher slopes being recorded in more mountainous areas. River bed slope is an important determinant of the geomorphology of the river, with higher slopes having more waterfalls, rapids and riffles than rivers with lower slopes. Rivers with more gentle sloped beds may have more meanders, sand bars and alluvial stretches.

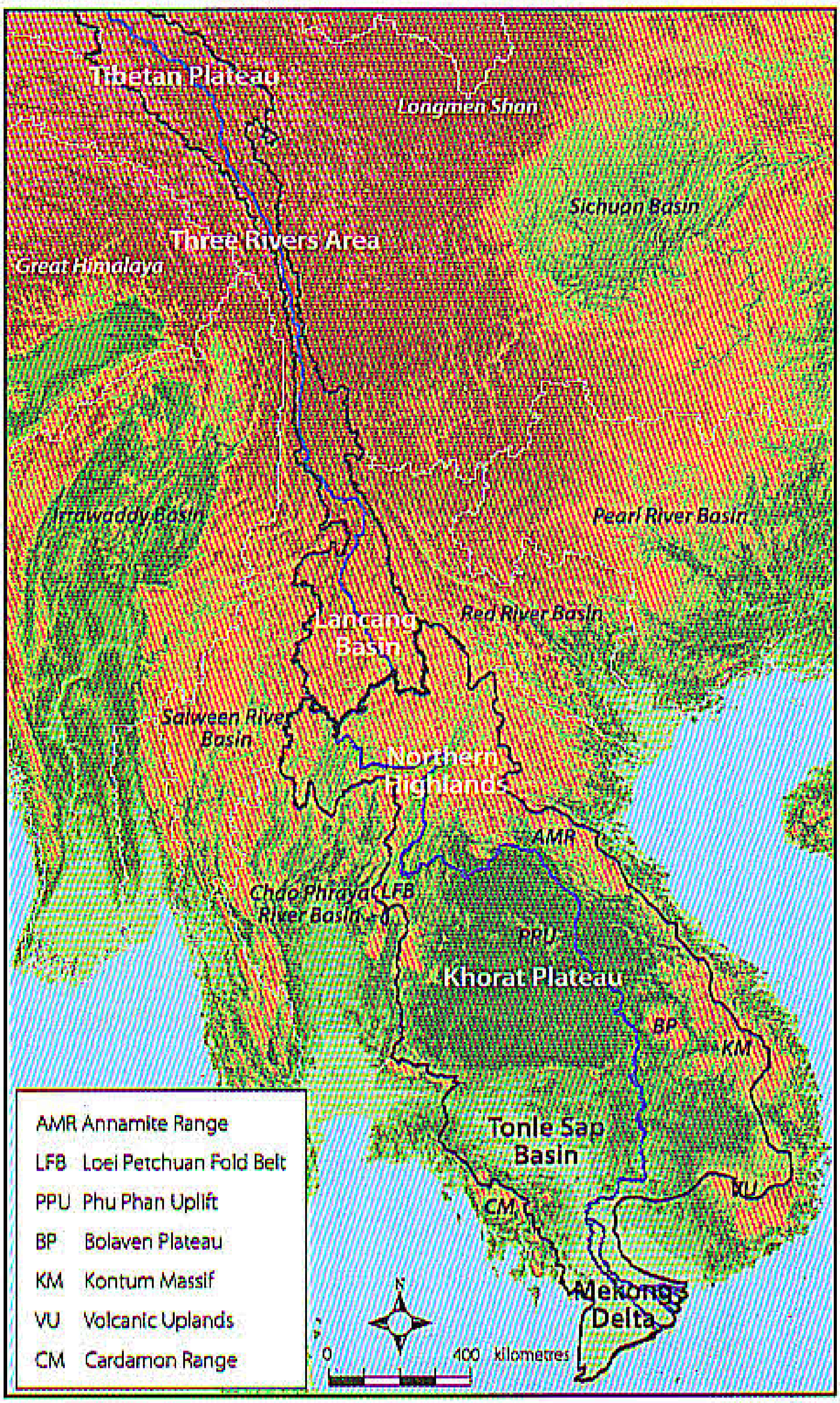
3.2.1.4 Geological area

The geology of a river basin is one of the main factors defining its ecological character of the river, especially its geomorphology and water quality. Seven physiographic regions of the Mekong have been defined (MRC,State of the Basin Report, 2010) of which three – the Tibetan Plateau, the Three Rivers area and the Lancang basin are in the Upper Mekong and are not considered further here. The other physiographic regions, shown in Figure 3-1, are used to group the tributaries for this analysis:

- **Northern Highlands**, which form the upland region of northern Thailand and Lao PDR, and with the Mekong constrained in steep-sided bedrock-cut channels. The major tributaries include the Nam Tha, Nam Ou, Nam Suong and Nam Khan coming in from the left bank, and the Nam Mae Kok and Nam Mae Ing from Thailand on the right bank. These tributary networks flow mostly through steep-sided rock-cut valleys but may broaden and develop floodplains, before entering the Mekong.

- **Khorat Plateau –** a saucer-shaped basin at an elevation of about 300 masl, defined by a group of highly resistant sandstones. The Khorat plateau is subdivided into two main sub-basin by a low range of hills that cut across the basin from NNW to SSE – Sakhon Nakhon/Savannakhet basin to the north and the Mun/Chi basin. The tributaries on the right bank include the Songkhram and Mun rivers which flow across the low gradient, low relief central region of the plateau with a well-developed dendritic form. The natural salt deposits in the strata underneath the Khorat plateau account for the poor soils in the Mun/Chi and Songkhram catchments, and raised salinity found in the Mun/Chi river.
- **Annamites –** opposite the Khorat plateau**, t**he tributaries from the left bank fall steeply from sources high in the Annamite mountains, passing through extensive karst limestone areas. These include the Nam Kadinh, Xe Bang Fai and Xe Bang Hieng.
- **Central Highlands of Vietnam** lie to the south of the Annamites and gives rise to the Three S rivers (Sekong, Sesan and Sre Pok), generally flowing through basement rocks (granites, basalts and high grade metamorphic rocks). To the north of these rivers, the Bolevan Plateau, with its geologically young lava flows and rich fertile soils, rises high above the Mekong with a number of smaller tributaries entering the Mekong to the west of the Plateau, or the Sekong river to the east.
- **Tonle Sap basin,** which can be subdivided into
  - **Cambodian northern plains,** which consist of extensive areas of old alluvium, with sandstone outcrops, draining the hills along the southern edge of the Khorat plateau. This area gives rise to the large tributaries of Stung Sreng, Stung Sen and Stung Chinit.
  - **Cardamon mountains,** rising to the south-west of the Tonle Sap so that the northern slopes of the Cardamons drains into the Tonle Sap, through tributaries such as the Stung Battambang, Stung Pursat and Stung Baribo. Sandstone predominates in this area leading into alluvial soils in the lower areas.
- **Mekong Delta –** the top of the delta is defined near Phnom Penh where the largest distributary channel – the Bassac river splits from the mainstream which then split further into a number of smaller distributary channels and man-made canals. The delta is principally alluvial in its geology, although there are a number of limestone karst outcrops.

Figure 3-1: Main physiographic regions of the Mekong



(Source MRC, 2010)

3.2.1.5 Limestone geology and caves

Limestone is perhaps the most important geological determinant for the tributaries affecting especially the pH of the water, as well as the ground water. Limestone landscapes tend to be relatively nutrient poor. The karst landscapes, especially caves and rivers running through them often have unique flora and fauna only found in that location.

3.2.1.6 Alluvial soils

Alluvial soils are indicative of floodplains. In this case fluvisols have been chosen to indicate the extent and presence of floodplain areas. However, limiting the assessment to this soil class alone is probably too restrictive for useful analysis, though the maps do show floodplains extending throughout the tributary network, especially in some of the flatter river systems such as the Mun and Chi rivers.

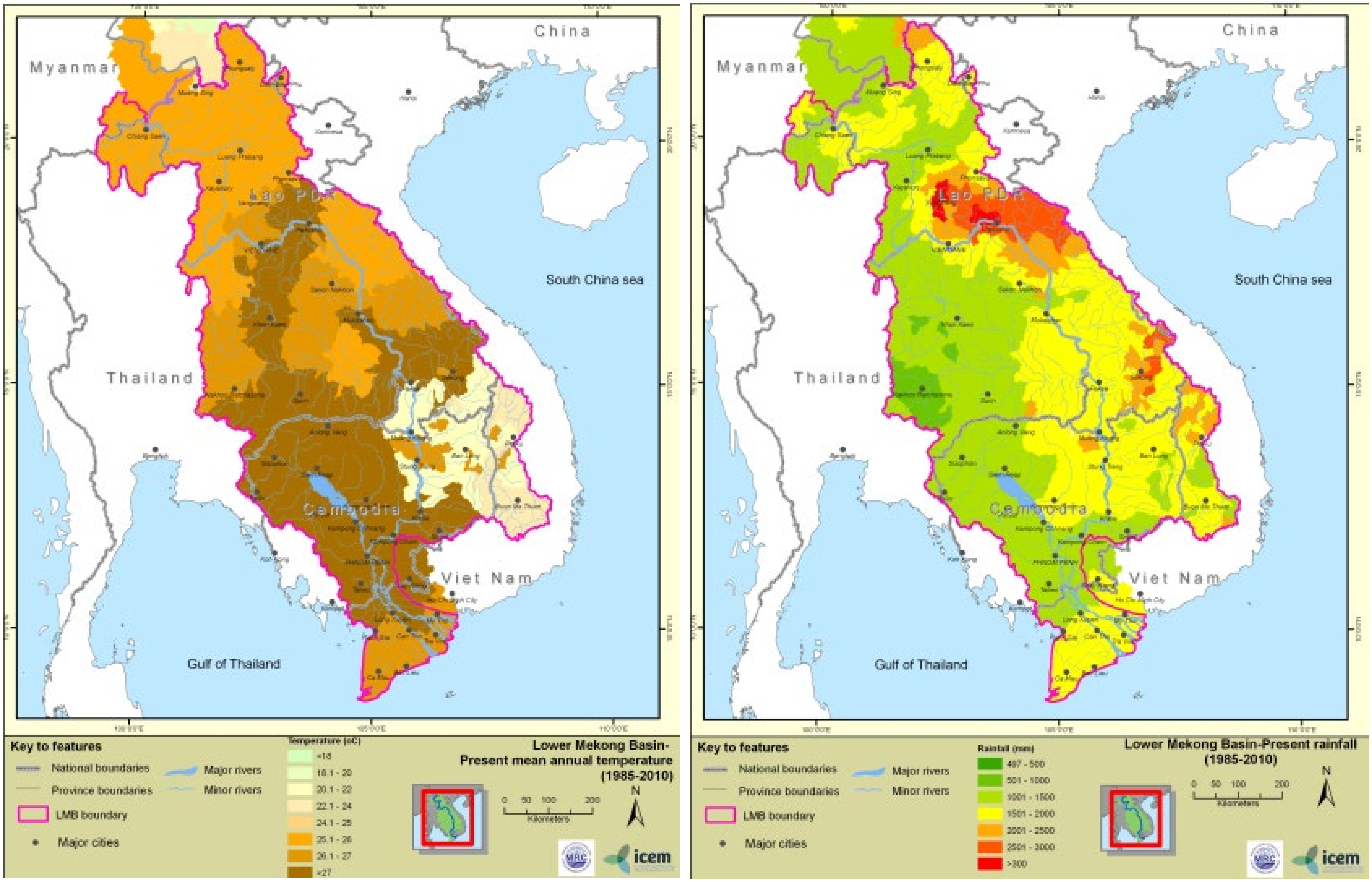
3.2.1.7 Geomorphology

Ideally an extensive assessment of the geomorphological features of the tributaries would be an essential part of determining their ecological significance. This would be a much larger exercise than has been available for this study, and examples are given of how this might be done by counting geomorphological features that are obvious from satellite imagery (e.g. Google Earth) such as rapids and riffles, water falls, sandbars, constrictions in the river channel that might indicate the presence of a deep pool, and meanders. Such an exercise has been done for Sesan river (Eric Baran, 2012) but a standard protocol for such analysis would be required before developing this further.

3.2.1.8 Climate

The climate parameters of mean annual temperature and mean annual rainfall are important for determining ecological characteristics of a tributary and its catchment. The distributions of different levels of these two parameters are shown in Figure 3-1. Analysis of differences of the tributaries based upon climate parameters alone does not appear to be very distinctive. Temperature and rainfall ranges have been included in the definition of the ecological zones (see section 3.3.2).

Figure 3-2: Distribution of present mean annual temperature and rainfall through the LMB



(Source: ICEM, 2011)

3.2.1.9 Water quality

Water chemistry – Conductivity, pH, hardness and levels of nutrients such as nitrate and phosphate are important determinants of the ecological character of rivers. Contamination with pollutants that reduce the dissolved oxygen content, increase the sediment and dissolved solids levels, and increase nutrients, will affect the ecological health of the tributaries. Ecological health assessments based on surveys of benthic and littoral invertebrates, diatoms etc. have also been undertaken in a number of locations.

The MRC has water quality records dating back to 1985, and have produced a series of water quality record sheets and reports, although these more often relate to the Mekong mainstream and some of the larger tributaries. It does NOT provide a comprehensive coverage of all the tributaries.

The MRCS are currently undertaking some statistical analysis of these water quality records and clearly identify groups of tributaries.

3.3 Biological characteristics

3.3.1 Protected areas and Key Biodiversity areas

The presence of protected areas (PA) within a catchment can be used as a proxy indicator of significance of a tributary. Protected areas have been established in all four countries of the LMB because specific ecosystems and species have been found in those areas. They include all the nationally protected areas according to the IUCN grading system, but do not include provincial or lower level protected areas. The protected areas are a form of land use that excludes other more ecologically damaging forms of land use, and serves to protect and conserve the biodiversity. For this indicator, the area under the PA system and % within the catchment is used as a measure of the extent of the catchment which is considered to be biodiversity rich. The area under the PA system and % within the LMB as a whole is used as a measure of the contribution of the catchment to the overall biodiversity of the Mekong, i.e. its significance.

Key Biodiversity Areas (KBAs): KBA status is triggered by the presence of key biodiversity criteria, informed by the IUCN Red List of Threatened Species™. KBA mapping builds upon the work of a number of existing partnership-supported initiatives - such as BirdLife International's Important Bird Areas, PlantLife International's Important Plant Areas, IUCN's Important Sites for Freshwater Biodiversity and sites identified by the Alliance for Zero Extinction - to map important sites for a wide range of critical biodiversity in marine, freshwater and terrestrial biomes. Data on KBA sites is compiled from an international network of local, national and international partners in NGOs, academic institutions and government agencies, and is compiled into the World Biodiversity Database (WBDB) managed by BirdLife International and Conservation International. The global inventory of terrestrial Important Bird Areas is nearly complete. Completeness of coverage varies for other taxa and biomes.[1] Within the Mekong basin, the Important Bird Areas are the only designation used to define KBAs. As with PAs, the

[1] KBA description taken from www.ibatforbusiness.org

measures are the area and % of KBA within the catchment and the area and % of the all the KBAs within the LMB.

One word of caution in interpreting the information about PAs and KBAs is that they have generally been developed from analysis of terrestrial ecosystems and biodiversity. It is possible therefore that the importance of this terrestrial biodiversity is not reflected in the aquatic ecology of the tributaries. However, we have made an assumption that the conditions that have made a rich terrestrial ecosystem also make a rich and significant aquatic ecosystem.

One special category of protected areas is Ramsar sites, which are the wetlands of international importance designated under the Ramsar Convention. Although there are a few exceptions within the LMB, e.g. Stung Treng, most of the Ramsar sites are associated with lakes and marshes rather than located on rivers. Nevertheless the presence of a Ramsar site in a catchment is considered to be an indication of aquatic ecological significance.

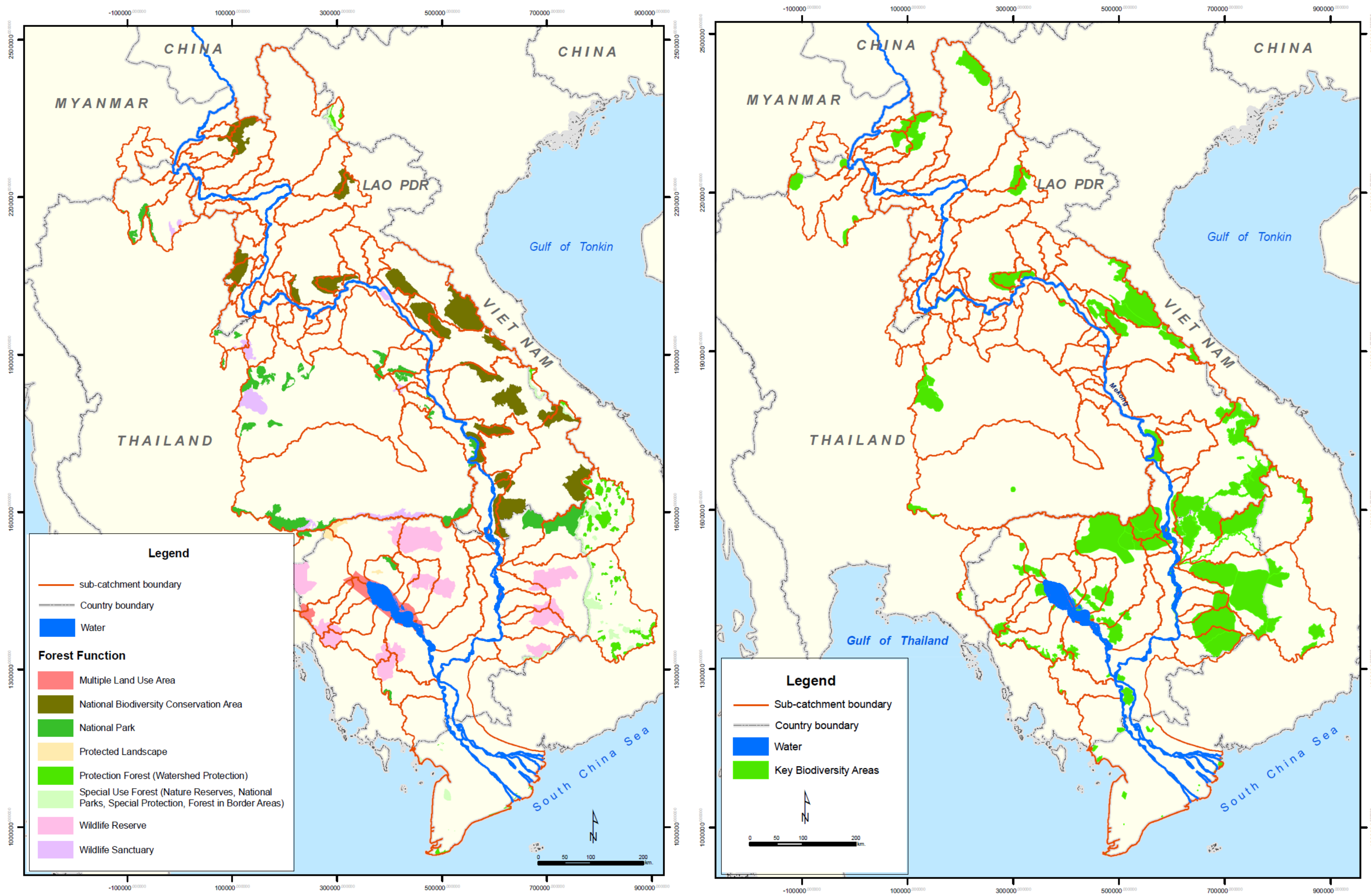
3.3.2 Ecological Zones

Over the past few years, WWF have developed a number of approaches to defining the ecological zones of the Greater Mekong, and in 2005, they called a meeting which included staff from Environment Programme of MRC to discuss a classification of the aquatic habitats in the Mekong basin.[2] They considered ecological functionality based upon hydro-geomorphic characteristics, such as system type (headwater vs. pass through water shed, small vs large streams, floodplain type), Elevation and derivatives such as slope, geology, vegetation, hydrology and stream network characteristics (river density and sinuosity). For the whole Mekong basin, they refined the GIS-based information and proposed the following classification and are shown in Figure 3-1.

Sub-basin classification	Stream classification
Montane grassland, savanna or shrubland	Montane river
Temperate coniferous or mixed forest	High elevation river
High elevation moist broadleafed forest	
Mid-elevation moist broadleafed forest	Mid-elevation draining wet area
Low-elevation moist broadleafed forest	Low elevation draining wet area
Mid-elevation dry broadleafed forest	Mid-elevation draining dry area
Low-elevation dry broadleafed forest	Low elevation draining dry area
Floodplain, wetland or lake	Mid-elevation river with floodplain
	Low-elevation river with floodplain
Swamp forest	Major floodplain river
Mangrove or delta	

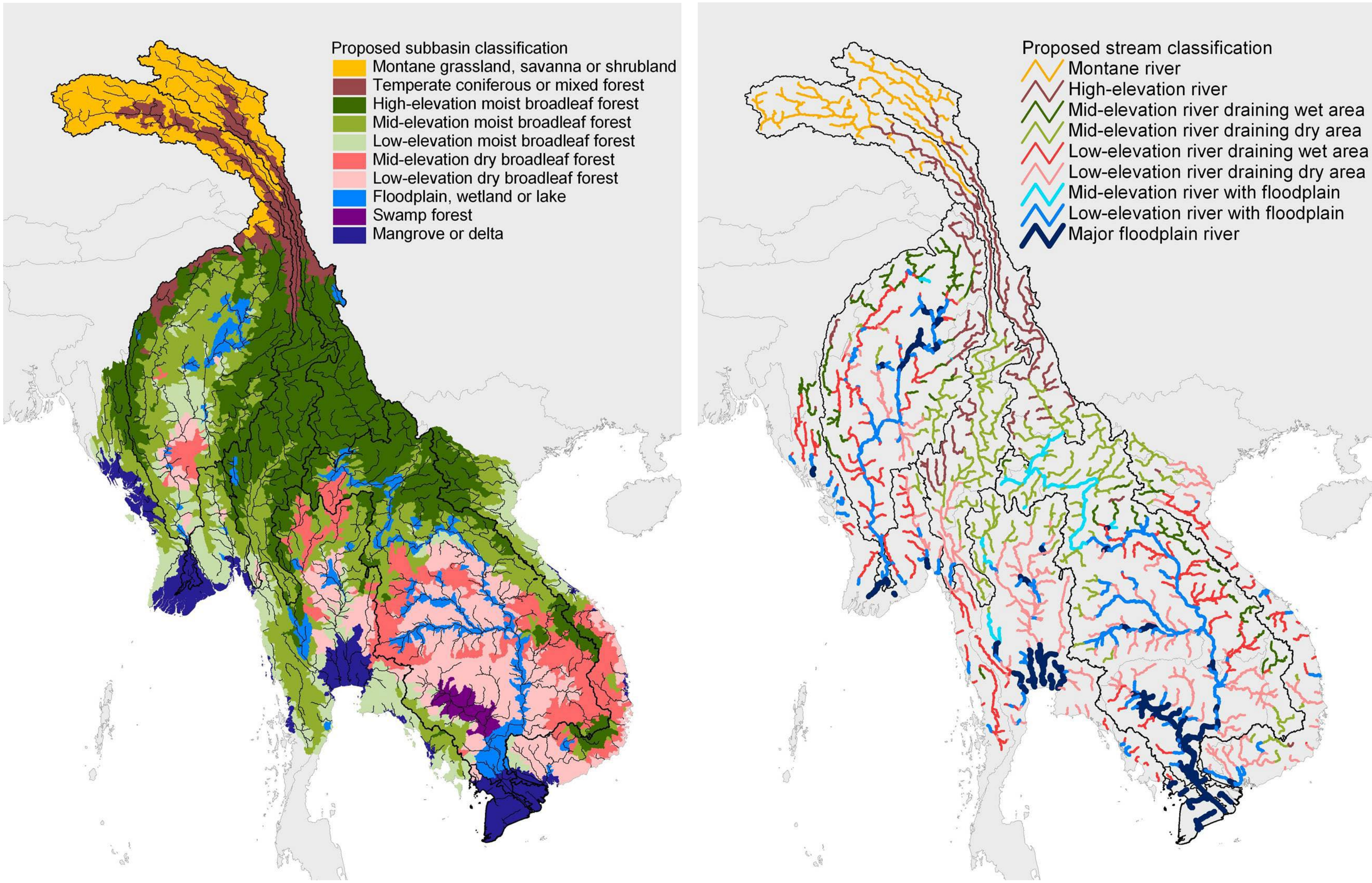
[2] WWF (2005) Habitat Classification Map workshop outputs (unpublished paper)

Figure 3-3: Distribution of Protected areas and Key Biodiversity Areas in the sub-catchments of the Lower Mekong



(Source: Meynell et al. 2011, Volume 2)

Figure 3-4: Greater Mekong Sub-basin and stream classification.



Source: WWF (2005)

This classification system has been used to define the proportion each tributary of the Mekong flowing through each ecological zone. Ecological zone profiles of the large tributaries have been produced, and an index of ecological zone diversity (EZDI) developed based upon the length of each stream order passing through each ecological zone. This index of ecological zone diversity has been used as a measure of significance in two ways – a tributary which has a high EZDI shows that there is a significant ecological diversity, whereas one that has a low EZDI with zones that are less common within the LMB is taken as an indication of uniqueness.

3.3.3 Tributary connectivity

The assessment of tributary connectivity and the degree of hydrological regulation in the Mekong has been developed by Bernhard Lerner with WWF Greater Mekong. This approach has drawn upon the earlier work of Nikolai Sindorf and Dang Thuy Trang described in Volume 2. A separate paper has been produced which describes the approach and method, and the results are incorporated into Section 6.3.

3.3.4 Biodiversity

There are a number of difficulties in presenting criteria for assessing the biodiversity significance of the tributaries. These largely relate to the absence of systematic assessments of biodiversity through many tributaries that can be compared. A survey of all the literature on the presence of different taxa and species in the tributaries has not been conducted, except for fish. For other taxa and species, there has been a reliance on the IUCN Red List of Endangered species. IUCN has recently conducted a comprehensive assessment of the following aquatic taxa:

- Aquatic and riverine plants
- Fish
- Amphibians
- Dragonflies
- Molluscs

Where possible, the locations of endangered species has been identified from the Red List and used to identify tributaries associated with them.

3.3.4.1 Fish

Fish is the only taxon to have been assessed for a number of tributaries and even here species lists are only available for 22 of the tributaries. These are composite species lists made up from several surveys which may not have used similar methods. Essentially the composite lists are records of presence, rather than abundance of the species.

The composite fish species lists from these 22 tributaries have been reviewed to identify:

- Total number of fish species recorded in the tributary
- Classification of these lists into native, endemic and introduced species, so that the numbers and make-up of the species lists can be compared
- Using the IUCN Red List to identify the numbers of species that are considered to be Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern and Data Deficient.

- Using the classification of fish into ten different fish guilds, as suggested by Halls and Kashatriya (2008). The fish guilds identify the usual habitat and migratory behavior of the species. The fish species lists have been considered and based upon knowledge of these species an initial allocation of the guild has been made. The fish guilds are as follows:
    1. Rithron resident guild
    2. Migratory main channel and tributaries resident guild
    3. Migratory, main channel spawner guild
    4. Migratory main channel refuge seeker guild
    5. Generalist guild
    6. Floodplain resident guild (Blackfish)
    7. Estuarine resident guild
    8. Semi-anadromous guild
    9. Catadromous guild
    10. Marine guild

    Plus No appropriate guild, Not known or no information and Non-native species

Ashley Halls has used these fish species lists of the 22 tributaries and through univariate and multivariate analysis comparing the species found with 33 different parameters described in this study. He has developed a predictive model of the distribution of fish species numbers, numbers and percentages of black fish (Guild 6) and migratory species (Guilds 2, 3, 4, 8 and 9), numbers and percentages of endemic species and endangered species likely to be found in each of the tributaries. The predictions of this model have been used in discussing their significance of the tributaries from a fish biodiversity perspective.

3.3.5 Other aquatic biodiversity

The analysis of other aquatic biodiversity in the tributaries has been based upon the IUCN Redlist which has recently been updated for the Mekong region. This is a qualitative assessment based upon identifying tributaries where Red-listed species are occurring.

- Aquatic and riverine plants
- Molluscs
- Odonata – dragon flies
- Amphibians
- Reptiles
- River dependent species of birds and mammals

Use of the presence if endangered species in different tributaries is dependent upon the research and survey work that has been carried out in these tributaries. Surveys have not been comprehensive, so whilst the presence of an endangered species in one tributary does not mean that it is present or absent from a tributary that has not been surveyed. The indicator is used to highlight tributaries where endangered species have been shown to exist.

3.3.6 Biomonitoring surveys

The following tributaries have been included in the MRC biomonitoring surveys in 2004 and 2007 (MRC, Dec 2006) (MRC, July 2009). These measure a) benthic diatoms, b) zooplankton, c) littoral macroinvertebrates and d) benthic macroinvertebrates. Although the numbers of tributaries where these surveys have been carried out is limited, the biomonitoring surveys are an indication of aquatic ecological health of the tributaries that have been surveyed. The results presented by the aquatic ecological health report cards published by the MRC have been used to identify the tributaries where ecological health appears to be changing. The results complement the water quality monitoring results because the organisms monitored reflect long-term changes in water quality.

- Nam Mae Kok (about 15 km above weir at Chiang Rai
- Nam Ou, 5km from confluence
- NamTon, 50 km upstream of Vientiane
- Nam Ngum below Nam Ngum dam
- Nam Ngum, upstream of confluence with Nam Lik
- Nam Mo (tributary of Nam Ngum, upstream of bridge near mine.
- Nam Songkhram about 7 km above confluence with Mekong
- Nam Songkhram mouth
- Nam Kading at Haad Sai Kam
- Nam Kham, Thailand
- Se Bang Fai
- Se Bang Hieng
- Mun river at Ban Tha Phae, Ubon Ratchathani
- Chi river at Wat Srithararam, Yasothon
- Mun / Chi/ Mekong confluence
- Se Done, at Ban He upstream of Pakse
- Se Kong in Laos on the Cambodian border
- Se Kong upper
- Se Kong mouth in Cambodia
- Se San-Sre Pok junction
- Se San
    - At Kontum hydrological station
    - at Pam Pi on Vietnam/Cambodia border
    - At Veun Sai
- Sre Pok
    - Vietnam
    - at Kampong Saila Lumpat
- Tonle Sap river
    - At Phnom Penh port
    - At Prek Kadam Ferry
- Pursat River, 4km above Prek Thot

3.4 Fisheries production

The fish species lists are an indication of the biodiversity in each tributary, but does not give any indication of fisheries productivity of the rivers. Two indicators of fish production have been developed for each tributary:

- **Based upon consumption** of fish and other aquatic animals (OAAs) by populations living within 5 km of the tributary, using average consumption figures for the different countries as estimated in MRC Technical Paper No 16.[3] This indicator may overemphasise the importance of tributaries that are more highly populated, especially the smaller tributaries, because it is dependent upon the population density.
- **Based upon the area of water surface** in each of the tributaries, using an average width of each of the stream orders multiplied by the stream length, and applying low, medium and high yield figures of kg/ha/year estimated for each country quoted in MRC Technical Paper No 16. These average yields are applied according to ecological zone to get a total potential yield of **resident** species (i.e. not including catches of migratory fish) in each tributary and also the yield per kilometer of stream length. This indicator has also been used to highlight tributaries that make the greatest contribution to catches of resident species in the LMB as a whole. Whilst the calculations may not be entirely accurate, because of differences in river width, the measure is useful as a relative indicator of the productivity of the tributary in comparison to others.

3.5 Extent of ecological change in the tributaries

All of the tributaries have experienced ecological changes to a greater or lesser extent mostly caused by human activity; none of them are pristine ecological river systems any more. The following parameters provide some indicators for the extent of these ecological changes.

3.5.1 Vegetation cover and landuse

Land use is one of the key factors influencing the changes in both terrestrial and aquatic ecosystems. The parameters used here are:

- **Forest cover** – but note that forest cover is changing very fast throughout the region and so the extent of forest cover measured in each catchment is not necessarily up to date or a true indication of the quality of the forest cover
- **Agriculture** –
    - **Rice Paddy** – both irrigated and rainfed
    - Other agriculture areas
        - **Swidden,**
        - **Field crops**
        - **Plantations**
- **Urban areas**

[3] MRC October 2007. Technical Paper No 16. Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin

The figures are taken from the MRC land use map for the LMB of 2003. The areas in each catchment of the different land uses are expressed both as a percentage of the catchment and as a percentage of the total area of that type of land use in the LMB.

In order to combine these land uses into a single index of land use modification, the percentages in each catchment of urban areas, rice paddy, and other agricultural areas have been added together and the sum divided by the most natural of the land uses – forest land use, even though this may not be a true indication of the actual forest cover or state of the forests. This index is indicative of the changes in the catchment, a land use modification index of less than 1 means that there is more than 50% forest land use in the catchment – thus the lower the index the less the catchment has been modified.

3.5.2 Human populations

The number of people living in each catchment is taken to indicate the pressures on water quality and use of natural resources. The higher the population and population density, the greater is the risk of water pollution from both domestic and industrial sources. The higher urban population emphasizes these risks to water quality. The higher rural population densities are taken to indicate a greater dependence and pressure upon the natural resources – both NTFP and fisheries resources. Three different measures have been estimated for each catchment:

- **Total populations** in the catchment and the overall **population density** – people/sq km
- **Urban-rural populations** – the distribution of these populations between urban and rural areas, and the percentage of the urban population within the LMB as a whole.
- **Populations living within 5 km of the tributary** – this is a new indicator which has been estimated from the number of villages living within 5 km on each side of the tributary, and the average population per village in that district. This has been converted into a **population density per kilometer of stream length**. This estimate has been used to determine the fish consumption figures from each tributary (see above)

3.5.3 Infrastructure

Three forms of major infrastructure development has had an influence upon the character of the rivers.

- **Roads** – road provide access to remote parts of the catchment and increase other uses and pressures upon the aquatic and terrestrial ecosystems. The construction of roads increases soil erosion and sediment transport down the rivers. The road database is relatively old and does not necessarily reflect the current position, but illustrates the use of road density within the catchment area (length of road/sq km) but also introduces a ***road/river index based upon the ratio of road to stream density in each catchment***
- **Irrigation** – irrigated areas are indicative of both use of the water from the tributary, and increased use of agricultural chemicals, and non-point source pollution from agriculture. Irrigation may also increase nutrient content of the run-off returning to the river. Two MRC datasets have been used for this indicator – one which estimates the total area irrigated in each catchment and the other the number of irrigation schemes existing and proposed in the basin. For comparative purposes, the ***percentage of irrigated area in the catchment*** has been used.

- **Hydropower** – hydropower impacts the tributaries by impounding and slowing down the water through reservoirs. The seasonal and daily flow patterns down the river are changed significantly, with water being stored in the wet season (peak flows reduced) and increased flows in the dry season. Daily flows may vary considerably depending upon the mode of operation of the hydropower scheme (e.g. peaking operation). Dams effectively break the connectivity of the rivers, preventing fish migrations and often trapping sediments, so that rivers downstream of dams carry less sediment. The MRC hydropower database has been used to identify existing and planned large hydropower dams in the tributaries, and identifying those which have the largest numbers of schemes. It does not identify all the small-scale hydropower (less than 30 MW which are being installed in many of the tributaries) and it must be noted that these may have similar impacts upon tributary connectivity, both with the Mekong and within the tributary system itself. For comparison of the tributaries a calculation of ***MW (existing installed capacity + potential large dams) per kilometer of total stream length*** has been used.

These three measures of infrastructure in a catchment have been graded in series of 0 – 4, where 0 indicates no infrastructure and 4 is the highest grade. For each tributary the infrastructure index is the sum of the grades for roads/river density, % irrigated areas and MW per km of stream length. The higher the score (up to 12) indicates the higher degree of modification by infrastructure.

4 Identifying ecologically significant tributaries

4.1 Objectives

The objective of this exercise is to highlight the most significant tributaries from both ecological and fisheries perspectives. This significance can have four main dimensions:

1. Ecological diversity – identifying those tributaries that contain the highest biodiversity whether measured by habitat or geomorphological diversity, or fish species diversity
2. Ecological uniqueness – identifying those tributaries that may be representative of relatively rare habitats, or ecological zones, or which may carry higher proportions of endemic or rare and endangered species, especially fish, or which may have higher proportions of protected areas.
3. Productivity – as measured by the estimates of fish yield in each tributary
4. Degree of modification – as measured by population density, landuse change and infrastructure such as roads, irrigation and hydropower.

In addition, estimates are also made of the degree of modification of the tributaries, showing which tributaries have the highest pressure from land use change, population or infrastructure.

4.2 Defining the catchments

One hundred and four catchments of the Lower Mekong have been identified by the MRC, with a total area of 624,654 sq km. These are listed with codes in Table 4-1 and outlined with code numbers in Figure 4-1.

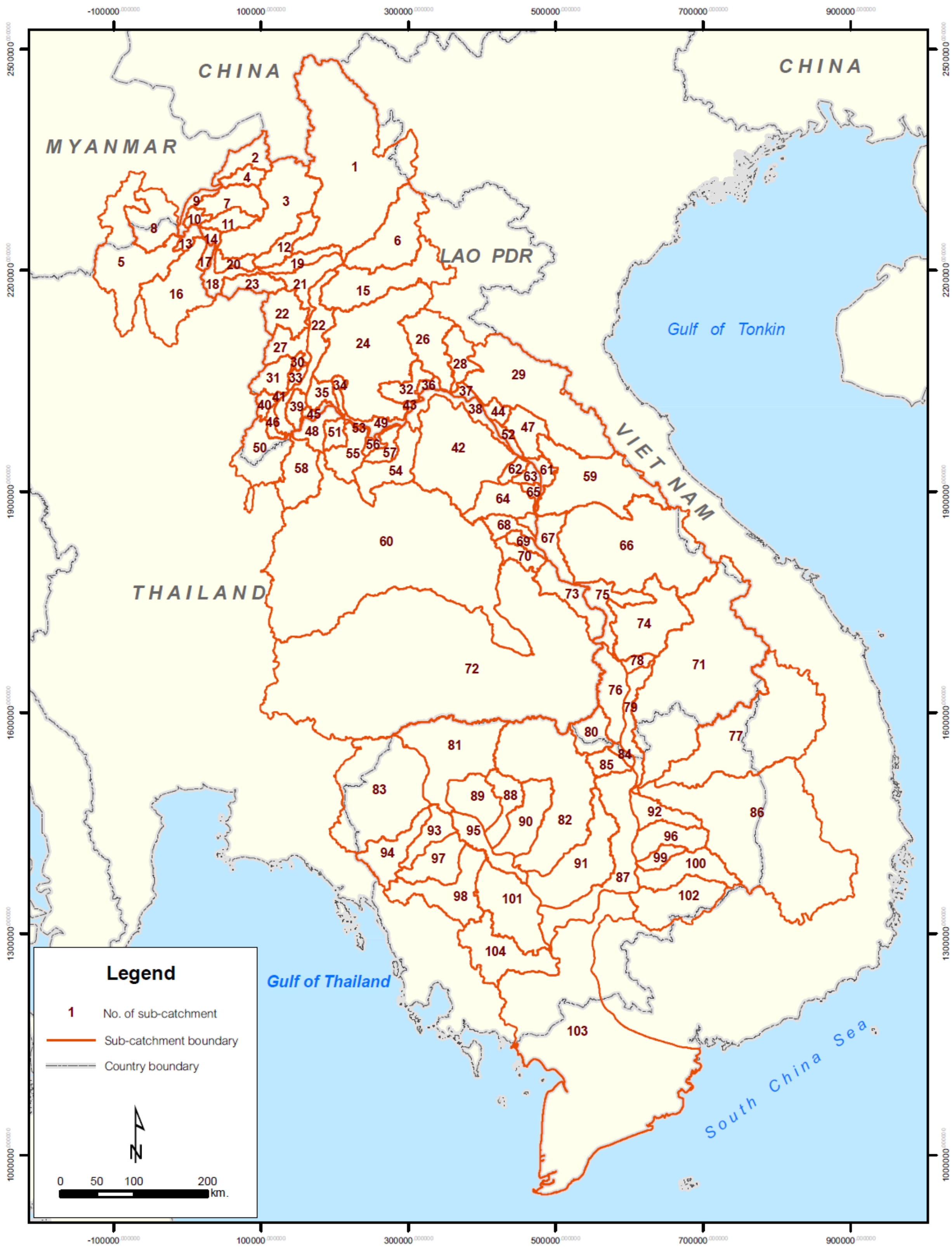
Not all of these catchments have major tributaries associated with them, though most do. These are usually the smaller catchments, which may have a number of first or second order streams discharging directly into the Mekong. Despite this, all have been considered in the analysis of the catchments. The largest of these is Siem Bok on the right bank of the Mekong in Cambodia, which has a number of smaller streams and channels that drain into the river, but also allow the water from the Mekong during high flows to flood overland to the Tonle Sap.

The Tonle Sap lake is also included in the list as a catchment to distinguish it from the rivers that discharge into the Great Lake, which are considered separately in their own right. In addition the Delta has also been considered, even though it consists of a network of natural *dis-tributaries* and man-made channels.

Table 4-1: Listing of all the catchments in the Lower Mekong Basin

Code	Catchment Name	Catchment Area		Code	Catchment Name	Catchment Area
		Sq km				Sq km
1	NAM OU	26,033		53	PHU PA HUAK	132
2	NAM NUAO	2,287		54	HUAI LUANG	4,090
3	NAM THA	8,918		55	HUAI MONG	2,700
4	NAM MA	1,141		56	H. KHOK	538
5	NAM MAE KOK	10,701		57	NAM SUAI	1,247
6	NAM SUONG	6,578		58	NAM LOEI	4,012
7	NAM PHO	2,855		59	SE BANG FAI	10,407
8	NAM MAE KHAM	4,079		60	NAM CHI	49,133
9	B.KHAI SAN	778		61	NAM MANG NGAI	944
10	NAM KEUNG	633		62	HUAI THUAI	739
11	NAM NGAOU	1,495		63	HUAI HO	691
12	NAM BENG	2,131		64	NAM KAM	3,495
13	DOI LUANG PAE MUANG	688		65	HUAI BANG HAAK	938
14	NAM NGAM	489		66	SE BANG HIENG	19,958
15	NAM KHAN	7,490		67	HUAI SOM PAK	2,516
16	NAM MAE ING	7,267		68	HUAI BANG SAI	1,367
17	NAM MAE NGAO	485		69	HUAI MUK	792
18	NAM KHOP	1,521		70	HUAI BANG I	1,496
19	NAM TAM	1,548		71	SE KONG	28,815
20	NAM NAGO	1,008		72	NAM MUN	70,574
21	NAM SING	2,681		73	H.BANG KOI	3,313
22	NAM PHUONG	4,139		74	SE DONE	7,229
23	NAM NGEUN	1,819		75	SE BANG NOUAN	3,048
24	NAM NGUM	16,906		76	Huai Khamouan	3,762
25	NAM HOUNG	2,872		77	SE SAN	18,888
26	NAM NHIEP	4,577		78	HUAI BANG LIENG	695
27	NAM PHOUL	2,095		79	HUAI TOMO	2,611
28	NAM SANE	2,226		80	Tonle Repon	2,379
29	NAM CADINH	14,822		81	ST.SRENG	9,986
30	NAM NHAH	316		82	St.Sen	16,360
31	NAM NHIAM	1,990		83	ST.MONGKOL BOREY	14,966
32	NAM MANG	1,836		84	PREK MUN	476
33	MUANG LIEP	488		85	O TALAS	1,448
34	NAM TON	587		86	SRE POK	30,942
35	NAM SANG	1,290		87	SIEM BOK	8,851
36	NAM THONG	455		88	ST.CHIKRENG	2,714
37	NAM KADUN	456		89	ST.SIEM REAP	3,619
38	H.BANG BOT	2,402		90	ST.STAUNG	4,357
39	NAM MI	1,032		91	ST.CHINIT	8,237
40	NAM PHONE	664		92	PREK PREAH	2,400
41	B.NAM SONG	138		93	ST.SANGKER	2,344
42	NAM SONGKHRAM	13,123		94	ST.BATTAMBANG	3,708
43	H.SOPHAY	186		95	TONLE SAP	2,744
44	NAM THON	838		96	PREK KRIENG	3,332
45	PHU LUONG YOT HUAI DUA	491		97	ST.DAUNTRI	3,696
46	NAM KAI	602		98	ST.PURSAT	5,965
47	NAM HINBOUN	2,529		99	PREK KAMP	1,142
48	H.NAM HUAI	1,755		100	PREK TE	4,364
49	H.MA HIAO	990		101	ST.BARIBO	7,154
50	NAM HEUNG	4,901		102	PREK CHHLONG	5,957
51	HUAI NAM SOM	1,072		103	DELTA	48,235
52	HOAAG HUA	626		104	PREK THNOT	6,124
					TOTAL	**624,654**

Figure 4-1: Map of the Lower Mekong Basin showing the different catchments by number



4.3 Grouping the tributaries by size

The first grouping of the tributaries of the Mekong is based upon the size of the catchment. Thus there are 27 Large catchments of over 5,000 sq km, 50 Medium sized catchments between 1,000 and 5,000 sq km and 27 Small catchments of less than 1,000 sq km. These are shown in descending size in Table 4-2.

Table 4-2: Grouping of tributaries by catchment size – Large, Medium and Small

Code	Tributary	Catchment area sq km	Code	Tributary	Catchment area sq km	Code	Tributary	Catchment area sq km
	LARGE			**MEDIUM**			**SMALL**	
72	NAM MUN	70,574	50	NAM HEUNG	4,901	49	H.MA HIAO	990
60	NAM CHI	49,133	26	NAM NHIEP	4,577	61	NAM MANG NGAI	944
103	DELTA	48,235	100	PREK TE	4,364	65	HUAI BANG HAAK	938
86	SRE POK	30,942	90	ST.STAUNG	4,357	44	NAM THON	838
71	SE KONG	28,815	22	NAM PHUONG	4,139	69	HUAI MUK	792
1	NAM OU	26,033	54	HUAI LUANG	4,090	9	B.KHAI SAN	778
77	SE SAN	18,888	8	NAM MAE KHAM	4,079	62	HUAI THUAI	739
24	NAM NGUM	16,906	58	NAM LOEI	4,012	78	HUAI BANG LIENG	695
82	ST. SEN	16,360	76	HUAI KHAMOUAN	3,762	63	HUAI HO	691
83	ST.MONGKOL BOREY	14,966	94	ST.BATTAMBANG	3,708	13	DOI LUANG PAE MUAN	688
29	NAM CADINH	14,822	97	ST.DAUNTRI	3,696	40	NAM PHONE	664
42	NAM SONGKHRAM	13,123	89	ST.SIEM REAP	3,619	10	NAM KEUNG	633
5	NAM MAE KOK	10,701	64	NAM KAM	3,495	52	HOAAG HUA	626
59	SE BANG FAI	10,407	96	PREK KRIENG	3,332	46	NAM KAI	602
81	ST.SRENG	9,986	73	H.BANG KOI	3,313	34	NAM TON	587
3	NAM THA	8,918	75	SE BANG NOUAN	3,048	56	H. KHOK	538
87	SIEM BOK	8,851	25	NAM HOUNG	2,872	45	PHU LUONG YOT HUAI	491
91	ST.CHINIT	8,237	7	NAM PHO	2,855	14	NAM NGAM	489
15	NAM KHAN	7,490	95	TONLE SAP	2,744	33	MUANG LIEP	488
16	NAM MAE ING	7,267	88	ST.CHIKRENG	2,714	17	NAM MAE NGAO	485
74	SE DONE	7,229	55	HUAI MONG	2,700	84	PREK MUN	476
101	ST.BARIBO	7,154	21	NAM SING	2,681	37	NAM KADUN	456
6	NAM SUONG	6,578	79	HUAI TOMO	2,611	36	NAM THONG	455
104	PREK THNOT	6,124	47	NAM HINBOUN	2,529	30	NAM NHAH	316
98	ST.PURSAT	5,965	67	HUAI SOM PAK	2,516	43	H.SOPHAY	186
102	PREK CHHLONG	5,957	38	H.BANG BOT	2,402	41	B.NAM SONG	138
	Total Large rivers	**459,659**	92	PREK PREAH	2,400	53	PHU PA HUAK	132
			80	TONLE REPON	2,379		**Total small rivers**	**15,855**
			93	ST.SANGKER	2,344			
			2	NAM NUAO	2,287			
			28	NAM SANE	2,226			
			12	NAM BENG	2,131			
			27	NAM PHOUL	2,095			
			31	NAM NHIAM	1,990			
			32	NAM MANG	1,836			
			23	NAM NGEUN	1,819			
			48	H.NAM HUAI	1,755			
			19	NAM TAM	1,548			
			18	NAM KHOP	1,521			
			70	HUAI BANG I	1,496			
			11	NAM NGAOU	1,495			
			85	O TALAS	1,448			
			68	HUAI BANG SAI	1,367			
			35	NAM SANG	1,290			
			57	NAM SUAI	1,247			
			99	PREK KAMP	1,142			
			4	NAM MA	1,141			
			51	HUAI NAM SOM	1,072			
			39	NAM MI	1,032			
			20	NAM NAGO	1,008			
				Total Medium rivers	**129,183**			

4.4 Grouping the tributaries by geological source area

Within these three size groupings, the geological source areas as shown in Figure 3-1 form sub-groups:

- **Northern Highlands,** with 7 large, 1 medium and 15 small catchments
- **Khorat Plateau with Loei-Petchuan Belt Fault,** with 3 large, 14 medium and 7 small catchments
- **Annamites,** with 4 large, 3 medium and 4 small catchments
- **Kontum Massif (Central Highlands of Vietnam), Bolevan Plateau and Volcanic Uplands of Vietnam,** with 4 large, 5 medium and 1 small catchment
- **Tonle Sap basin,**
    - **Cambodian northern plains,** with 5 large, 4 medium and no small catchments
    - **Cardamon mountains,** with 3 large, 3 medium and no small catchments
    - **Tonle Sap Great Lake**
- **Mekong Delta** with 1 large catchment

NORTHERN HIGHLANDS		
Code	Tributary	Catchment area
1	NAM OU	26,033
3	NAM THA	8,918
5	NAM MAE KOK	10,701
6	NAM SUONG	6,578
15	NAM KHAN	7,490
16	NAM MAE ING	7,267
24	NAM NGUM	16,906
39	NAM MI	1,032
9	B.KHAI SAN	778
10	NAM KEUNG	633
13	DOI LUANG PAE MUANG	688
14	NAM NGAM	489
17	NAM MAE NGAO	485
30	NAM NHAH	316
33	MUANG LIEP	488
34	NAM TON	587
36	NAM THONG	455
40	NAM PHONE	664
41	B.NAM SONG	138
43	H.SOPHAY	186
45	PHU LUONG YOT HUAI DUA	491
46	NAM KAI	602
49	H.MA HIAO	990

KHORAT PLATEAU + LOEI PETCHUAN FOLD BELT			
Code	Tributary	Catchment area	Geological zone
42	NAM SONGKHRAM	13,123	KP
60	NAM CHI	49,133	KP
72	NAM MUN	70,574	KP
38	H.BANG BOT	2,402	KP
48	H.NAM HUAI	1,755	KP
50	NAM HEUNG	4,901	LFB
51	HUAI NAM SOM	1,072	LFB
54	HUAI LUANG	4,090	LFB
55	HUAI MONG	2,700	LFB
57	NAM SUAI	1,247	LFB
58	NAM LOEI	4,012	LFB
64	NAM KAM	3,495	KP
68	HUAI BANG SAI	1,367	KP
70	HUAI BANG I	1,496	KP
73	H.BANG KOI	3,313	KP
76	HUAI KHAMOUAN	3,762	KP
80	TONLE REPON	2,379	KP
53	PHU PA HUAK	132	LFB
56	H. KHOK	538	LFB
62	HUAI THUAI	739	KP
63	HUAI HO	691	KP
65	HUAI BANG HAAK	938	KP
69	HUAI MUK	792	KP
84	PREK MUN	476	KP

ANNAMITE MOUNTAINS		
Code	Tributary	Catchment area
29	NAM CADINH	14,822
59	SE BANG FAI	10,407
66	SE BANG HIENG	19,958
74	SE DONE	7,229
47	NAM HINBOUN	2,529
67	HUAI SOM PAK	2,516
75	SE BANG NOUAN	3,048
37	NAM KADUN	456
44	NAM THON	838
52	HOAAG HUA	626
61	NAM MANG NGAI	944

Kontum Massif, Bolevan Pleateau, Volcanic Uplands			
Code	Tributary	Catchment area	Geological zone
71	SE KONG	28,815	KM
77	SE SAN	18,888	KM
86	SRE POK	30,942	KM
102	PREK CHHLONG	5,957	VU
79	HUAI TOMO	2,611	BP
92	PREK PREAH	2,400	KM
96	PREK KRIENG	3,332	KM
99	PREK KAMP	1,142	KM
100	PREK TE	4,364	VU
78	HUAI BANG LIENG	695	BP

Tonle Sap basin (Cardamon mountains, Northern tributaries of Tonle Sap)			
Code	Tributary	Catchment area	Geological zone
81	ST.SRENG	9,986	NTS
82	ST. SEN	16,360	NTS
83	ST.MONGKOL BOREY	14,966	NTS
87	SIEM BOK	8,851	NTS
91	ST.CHINIT	8,237	NTS
98	ST.PURSAT	5,965	CM
101	ST.BARIBO	7,154	CM
104	PREK THNOT	6,124	CM
85	O TALAS	1,448	NTS
88	ST.CHIKRENG	2,714	NTS
89	ST.SIEM REAP	3,619	NTS
90	ST.STAUNG	4,357	NTS
93	ST.SANGKER	2,344	CM
94	ST.BATTAMBANG	3,708	CM
95	TONLE SAP	2,744	TS
97	ST.DAUNTRI	3,696	CM

Delta		
Code	Tributary	Catchment area
103	DELTA	48,235

5 Assessing physical indicators of ecological significance

In this analysis the rivers with the largest catchments in the different geological zones are considered for their physical attributes – the longest rivers, the steepest rivers and the highest rivers, and their stream density. For ease of comparison of the different parameters within each size range, the rivers have been classified in three groups based on 3 = 80th percentile (colour code: orange), 2 = 50th percentile (colour code: pink) and 1 = below 50th percentile (colour code: white). The actual values can be found in Volume 2.

5.1 Physical attributes

5.1.1 Large catchments

5.1.1.1 Northern Highlands

In the Northern Highlands, the Nam Ou is the longest with the highest number of stream orders, and with the greatest proportion in stream orders 1 and 2. It is followed by Nam Ngum, which also has a significant proportion of streams in stream orders 3 and 4.

The Nam Ou, Nam Suong, Nam Khan and Nam Ngum have the steepest slopes in 1st and 2nd order streams. The rivers with the highest stream density are the Nam Ou and Nam Mae Ing.

The two highest rivers are the Nam Ngum and Nam Mae Kok, both with significant proportions of the river over 1,500 masl and above 1,000 masl, also shared by the Nam Ou. The Nam O, Nam Khan both have significant proportions of river between above 1000 masl and above 500 masl. The Nam Mae Ing is the lowest of the Northern Highlands tributaries with the greatest proportion between 100 and 500 masl. The Nam Ngum, Nam Mae Kok and Nam Ou are the rivers with the greatest spread over elevations between 100 and over 1,500 masl.

Table 5-1: Significance groups for physical characteristics of large tributaries in Northern Highlands

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
1	NAM OU	26,033	NH	2,443	3	3	3	1	2	3	3	2	-	1	3	3	2
3	NAM THA	8,918	NH	2,203	1	1	2	2		2	1	1	-	1	3	2	-
5	NAM MAE KOK	10,701	NH	2,115	1	2	1	2	1	2	2	1	-	1	2	2	3
6	NAM SUONG	6,578	NH	2,453	1	1	3	1		3	3	1	-	1	3	2	-
15	NAM KHAN	7,490	NH	2,467	1	1	1	1	2	3	3	1	-	1	3	3	1
16	NAM MAE ING	7,267	NH	2,176	1	2	1	3		1	1	2	-	3	1	-	-
24	NAM NGUM	16,906	NH	3,039	2	2	1	2	1	3	2	1	-	2	1	3	3

In summary, the large tributaries in the Northern Highlands which stand out from their physical characteristics are the Nam Ou, Nam Ngum and Nam Mae Kok.

5.1.1.2 Khorat Plateau and Loei Petchuan Fold Belt

In the Khorat Plateau there are only three large rivers, and these include the largest of the Mekong tributaries – the Nam Mun and Nam Chi, and the Nam Songkhram. These two have the longest and largest numbers of stream orders, and all three have the largest percentages of their total length in stream orders 3 and 4. As expected from the topography of the Khorat Plateau, they have a low average slope for both 1 and 2 stream orders, and all three have the largest proportion in the 100 to 500 masl elevation. The Nam Songkhram has a higher stream density than the Nam Chi or Nam Mun.

Table 5-2: Significance groups for physical characteristics of large tributaries in Khorat Plateau

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
42	NAM SONGKHRAM	13,123	KP	3,265	2	2	1	3	1	1	1	2	-	3	-	-	-
60	NAM CHI	49,133	KP	*3,632	3	3	1	3	3	1	1	1	-	3	1	1	-
72	NAM MUN	70,574	KP	3,632	3	3	1	3	1	1	1	1	1	3	1	-	-

In summary, the Nam Mun and Nam Chi are very significant rivers of the Khorat Plateau, followed closely by the Nam Songkhram. All three have very different physical parameters compared to the large tributaries of the Northern Highlands above.

5.1.1.3 Annamites

Of the tributaries arising in the Annamite mountains, the Nam Cadinh and the Se Bang Hieng, stand out as middle range lengths of streams, though the Se Bang Hieng has the largest number of streams. The Se Bang Hieng and the Se Done have the highest stream density compared with low levels of the Nam Cadinh and Se Bang Fai. The Se Done has the highest proportion of stream length in stream order 1 and 2, although all of the Annamite large tributaries have a middle range of stream length in stream orders 1 and 2. All of the Annamite mountain rivers have a middle range of steepness in both stream orders 1 and 2, apart from the Se Bang Fai. Whilst both the Nam Cadinh and the Se Bang Hieng arise at elevations above 1,500 masl, the Nam Cadinh has a much higher proportion of its length over 1,000 masl and over 500 masl. The Se Bang Fai has a very high proportion of its length between 100 and 500 masl. The Se Bang Hieng and Se Done have a similar elevation structure, though the former arises at a higher level.

Table 5-3: Significance groups for physical characteristics of large tributaries in Annamite mountains

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
29	NAM CADINH	14,822	AMR	3,173	2	1	2	1	1	2	2	1	-	1	2	2	1
59	SE BANG FAI	10,407	AMR	3,364	1	1	2	2		1	2	1	-	3	1	-	-
66	SE BANG HIENG	19,958	AMR	3,496	2	3	2	1	1	2	2	3	-	2	1	1	1
74	SE DONE	7,229	AMR	3,677	1	2	3	1		2	2	3	1	2	1	1	-

In summary, the physical characteristics of large tributaries arising in the Annamite mountains indicate that the Nam Cadinh and Se Bang Hieng stand out as more significant, though the Se Bang Fai is significant because of the greater proportion lying at lower elevation.

5.1.1.4 Central Highlands, Bolevan Plateau and Volcanic uplands

The large tributaries arising from volcanic geological formations, include the 3S rivers and Prek Chhlong. The longest river, with the largest number of streams is the Sre Pok, followed by the Se Kong and Se San. All four rivers have a middle range of proportions of length at stream orders 1 and 2, and the Se San stands out as having a higher proportion of stream length for stream orders 3 and 4. The Sre Pok as a more complex river has a higher proportion of length at stream orders 5 and 6. The Se Kong is the steepest river, especially for 2nd order streams, followed by the Sre Pok and the Se San. The Prek Chhlong has lowest slopes. However, the Prek Chhlong has the highest stream density of all these rivers, followed by the Sre Pok. The Se Kong has the highest proportions of its length arising over 1,500 masl, extending down to less than 100 masl. The Se San and Sre Pok have similar elevation profiles. The Prek Chhlong starts between 500 and 1,000 masl, with a higher proportion of its length from below 100 to above 500 masl.

Table 5-4: Significance groups for physical characteristics of large tributaries from Kontun Massif and Volcanic Uplands

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
71	SE KONG	28,815	KM	3,901	2	2	2	1	1	2	3	1	1	2	2	3	2
77	SE SAN	18,888	KM	3,901	2	1	2	2		1	2	1	1	2	2	1	-
86	SRE POK	30,942	KM	3,901	3	3	2	1	2	2	2	2	1	2	2	1	-
102	PREK CHHLONG	5,957	VU	4,077	1	1	2	1		1	1	3	2	2	1	-	-

In summary, the 3S rivers stand out as being very significant, with the Se Kong having steeper slopes and a wider and higher elevation profile than the Se San and Sre Pok, but with the Sre Pok being longer and with a more complex structure. The Prek Chhlong is significant of these rivers arising from volcanic geology in that it is lower and with a higher stream density.

5.1.1.5 Tonle Sap basin and Delta

The large tributaries that flow into the Tonle Sap, are very different from the preceding tributaries and can be subdivided into those flowing from the northern plains of Cambodia and those arising from the Cardamon mountains. The Siem Bok catchment does not have any major tributary flowing into the Mekong, although it has a number of smaller streams. This is illustrated by the high number of stream orders 1 and 2 in comparison to the other catchments flowing into the Tonle Sap, and the highest stream density. Forming the west bank of the Mekong below Stung Treng, in its lower parts it is important for surface flooding back into the Tonle Sap when the Mekong is high. As largely floodplain rivers, these tributaries flowing into the Tonle Sap have low slopes, apart from the Stung Mongkol Borey, and a high proportion of lengths of higher order streams, (stream orders 3 and 4, and 5 and 6).

The Stung Mongkol Borey and Stung Chinit have middle order stream densities. The Stung Mongkol Borey arises at an elevation between 500 and 1,000 masl, whilst all the rest coming from the north into the Tonle Sap arise between 100 and 500 masl with the greatest proportion lying below 100 masl.

In contrast, of the three large rivers coming from the Cardamon Mountains, the Stung Baribo and Stung Pursat flow into the Tonle Sap, and the Prek Thnot flows into the Mekong directly from the eastern end of the Cardamons. These are relatively short rivers, with higher length proportions at stream orders 3 and 4 and 4 and 5. The Stung Pursat has the highest slopes for both stream orders 1 and 2, and Stung Baribo has a middle range slope for stream order 1. All three rivers from the Cardamon mountains have a high stream density. Stung Baribo and Prek Thnot both rise at elevations over 1,500 masl, with Stung Baribo having a significant proportion of its length over 1,500 masl. All three rivers have a wider elevation profile from over 1,000 masl to less than 100 masl.

The Delta stands out as a unique catchment extending from Cambodia down to the sea, but with a very large stream length, most of which are in stream orders 1 and 2. It has very low slopes for stream orders 1 and 2, and a low stream density. It has the highest proportion of its length lying below 100 masl.

Table 5-5: Significance groups for physical characteristics of large tributaries around Tonle Sap and Delta

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
81	ST.SRENG	9,986	NTS	TS	1	1	1	2	2	1	1	1	2	1	-	-	-
82	ST. SEN	16,360	NTS	TS	1	1	1	1	3	1	1	1	2	1	-	-	-
83	ST.MONGKOL BOREY	14,966	NTS	TS	1	2	1	2	2	1	2	2	2	1	1	-	-
87	SIEM BOK	8,851	NTS		2	2	3	1	1	1	1	3	3	1	-	-	-
91	ST.CHINIT	8,237	NTS	TS	1	1	1	2	3	1	1	2	3	1	-	-	-
98	ST.PURSAT	5,965	CM	TS	1	1	1	3	1	3	3	3	1	2	2	1	-
101	ST.BARIBO	7,154	CM	TS	1	1	1	2	2	2	1	3	2	1	1	1	2
103	DELTA	48,235	D	4,313	3	1	3	1		1	1	1	3	1	-	-	-
104	PREK THNOT	6,124	CM	4,285	1	1	2	1	3		1	3	1	2	1	1	1

In summary, the large tributaries flowing into the Tonle Sap and Delta can be divided into the northern plain rivers and the Cardamon mountain rivers. Of the northern plain rivers, the Stung Sen stands out as the largest followed by the Stung Mongkol Borey which has the higher elevation profile, and slope. The Siem Bok catchment does not have a single main point of discharge into the Mekong, but is an important floodplain catchment. Of the Cardamon mountain tributaries, the Stung Baribo is significant from its elevation profile and height, and with the Stung Pursat and Prk Thnot has the highest stream density. The Delta is also a unique catchment because of its low elevation and high proportion of first and second order streams and very low slopes.

5.1.2 Medium catchments

Tributaries with medium sized catchments are analysed in the same way, considering the geological source of the rivers.

5.1.2.1 Northern Highlands

In the Northern Highlands the Nam Mae Kok stands out as having the longest and highest number of stream orders, and this is reflected in the stream density. The Nam Houng also has a high stream density. The more northerly tributaries tend to have greatest proportion of stream order lengths in their first order streams, though the Nam Mae Kham and Nam Houng have a high proportion of 2nd order stream lengths. The slope of the first order streams are highest in the Nam Mae Kham, and the group of medium sized tributaries that feed into the Mekong from Pak Beng, to Xayaboury such as Nam Khop, Nam Tam, Nam Nago, Nam Sing, Nam Phuong, Nam Huong and Nam Phoul. Many of these also have steep slopes in the 2nd order tributaries. The Nam Nhiep stands out as having the greatest proportion of its stream length at elevations over 1,500 masl, and between 1,000 – 1,500 masl. Other high tributaries include the Nam Nuao, Nam Tam, and Nam Sane, and these also flow through a wide range of elevations from 1,500 through to over 100 masl. The Nam Sang and Nam Mi stand out because they have their entire lengths between 100 and 500 masl.

Table 5-6: Significance groups for physical characteristics of medium tributaries in Northern Highlands

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
2	NAM NUAO	2,287	NH	1,966	1	1	3			2	3	1		1	2	3	2
4	NAM MA	1,141	NH	1,998	1	1	3			2		1		1	2	3	
7	NAM PHO	2,855	NH	2,005	1	1	2	1		2	2	1		1	3	1	
8	NAM MAE KHAM	4,079	NH	2,112	3	3	1	3	2	3	2	3		2	2	2	1
11	NAM NGAOU	1,495	NH	2,154	1	1	3			2	1	1		1	3		
12	NAM BENG	2,131	NH	2,307	1	1	3			2	3	1		1	3		
18	NAM KHOP	1,521	NH		1	2	2	1		3	3	2		1	2	2	
19	NAM TAM	1,548	NH		1	1	3			3	3	1		2	2	2	2
20	NAM NAGO	1,008	NH		1	1	3			3	3	2		1	3	2	
21	NAM SING	2,681	NH		2	2	3			3	3	1		2	1	1	
22	NAM PHUONG	4,139	NH		1	2	3	1		3	3	1		2	1	1	
23	NAM NGEUN	1,819	NH	2,322	1	1	2	1		2	2	1		1	3	1	
25	NAM HOUNG	2,872	NH		2	1	1	3		3	3	2		1	2	3	1
26	NAM NHIEP	4,577	NH	3,123	2	2	1	2	1	3	2	1		1	1	3	3
27	NAM PHOUL	2,095	NH	2,581	1	1	2	1		3	3	1		2	2	1	
28	NAM SANE	2,226	NH	3,130	2	1	1	2	1	2	3	2		2	1	2	2
31	NAM NHIAM	1,990	NH	2,686	1	1	1	2	1	2	2	1		2	1		
32	NAM MANG	1,836	NH	3,080	1	1	2	1	1	2	2	2		2	2	1	
35	NAM SANG	1,290	NH	2,881	1	1	3	1		1	2	1		3			
39	NAM MI	1,032	NH		1	1	3			1		1		3			

In summary, the medium sized tributaries in the Northern Highlands that stand out include the Nam Mae Khok which is the longest with the highest stream density, the tributaries that flow into the Mekong between Pak Beng and Xayboury which have the highest slopes, and the Nam Nhiep which has the highest proportion at higher elevations. The Nam Sang and Nam Mi are restricted to elevations between 100 – 500 masl.

5.1.2.2 Khorat Plateau and Loei Petchuan Fold Belt

Of the medium-sized tributaries in North East Thailand, the Nam Huang and Huai Luang in the Loei Petchuan Fold Belt (LFB) have the longest lengths. There is not a great deal of difference in the stream densities, though many of the rivers in the LFB have higher stream densities than most of the rivers on the Khorat Plateau. The Huai Luang, Nam Suai and Nam Kam have the greatest proportion of their lengths in stream orders 3 and 4. There is not much difference in the slopes of these rivers as is to be expected from the topography of the Khorat Plateau. Apart from the Nam Heung which arises from an elevation of over 1,500 masl (and is on the boundary between Lao and Thailand near Pak Lay), all the other medium sized tributaries flow at elevations between 100 and 500 masl. At the southeastern end of the Plateau, the H. Bang Koi, Huai Khamouan and Tonle Repon all have some lengths below 100 masl.

Table 5-7: Significance groups for physical characteristics of medium tributaries in Khorat Plateau / Loei Petchuan Fold Belt

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
38	H.BANG BOT	2,402	KP	3,071	2	2	2	1	1	1	1	2		3			
48	H.NAM HUAI	1,755	KP		1	1	2	1		2	2	1		3			
50	NAM HEUNG	4,901	LFB	2,778	3	3	1	2	1	2	2	2		1	2	2	1
51	HUAI NAM SOM	1,072	LFB	2,903	1	1	1	2		1	1	1		3			
54	HUAI LUANG	4,090	LFB	3,023	3	3	1	3	2	1	1	2		3			
55	HUAI MONG	2,700	LFB	2,952	2	2	1	2	1	1	1	2		3			
57	NAM SUAI	1,247	LFB	3,014	1	1	1	3		1	1	2		3			
58	NAM LOEI	4,012	LFB	2,789	2	1	1	2	2	1	2	1		3			
64	NAM KAM	3,495	KP	3,366	2	2	1	3		1	1	2		3			
68	HUAI BANG SAI	1,367	KP	3,401	1	1	1	1		2	2	1		3			
70	HUAI BANG I	1,496	KP	3,439	1	1	2	1		1	1	1		3			
73	H.BANG KOI	3,313	KP		2	3	2	1	2	2	2	2	1	2			
76	HUAI KHAMOUAN	3,762	KP	3,750	2	2	1	2		1	2	1	2	1			
80	TONLE REPON	2,379	KP	3,813	1	1	1	2		1	1	1	1	1			

In summary, the medium sized tributaries in North East Thailand appear to be quite similar in physical characteristics, although those in the LFB stand out as being slightly different, from their stream structure. The Nam Heung stands out as arising at much higher elevations and may also be considered as part of the Northern Highland group of tributaries. Apart from the south eastern tributaries discharging into the Mekong between the Pak Mun confluence and Khone Falls, which have proportions of their length below 100 masl, all the other rivers lie between 100 and 500 masl.

5.1.2.3 Annamites

There are only three medium sized tributaries arising in the Annamite region – the Nam Hinboun and Huai Som Pak and Se Bang Nouan. The Nam Hinboun and Se Bang Nouam have distinct confluences with the Mekong, the Huai Som Pak having a series of low order streams entering the Mekong, which would account for its high proportion of stream orders 5 and 6, and higher stream density. The Se Bang Nouan has a much higher stream density and higher slopes than the other two. The Huai Som Pak flows at elevations between 100 to 500 masl, but the Nam Hinboun arises over 1,000 masl and flows into the Mekong at between 100 - 500 masl. The Se Bang Nouan arises between 500 and 1,000 masl, and both have small proportions of their lengths at elevations below 100 masl.

Table 5-8: Significance groups for physical characteristics of medium tributaries in Annamite mountains

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
47	NAM HINBOUN	2,529	AMR	3,282	1	1	2	1	1	1	1	1	1	2	1	1	
67	HUAI SOM PAK	2,516	AMR		2	2	2	1	3	1	1	2		3			
75	SE BANG NOUAN	3,048	AMR	3,517	3	3	1	1		2	2	3	1	2	1		

In summary, there are few medium sized tributaries arising from the Annamite region and the nam Hinboun and Se Bang Nouan appear to be similar, although the latter has much higher length and stream density and slope. The Nam Hinboun arises at a higher elevation, but otherwise has a similar elevation profiles.

5.1.2.4 Central Highlands, Bolevan Plateau and Volcanic uplands

The Medium-sized tributaries arising from the volcanic geological zones tend to be longer than those considered above, with higher stream densities, and greater lengths in stream orders 1 and 2. However, the slopes are relatively low for both stream orders 1 and 2, in comparison to the Northern Highland rivers. Apart from the Huai Tomo which flows from the Bolevan from elevations of between 1,000 and 1,500 masl, three of the 4P rivers (Prek Preah, Prek Krieng and Prek Kamp) arise between 100 and 500 masl and have most of their lengths at elevations below 100 masl. The fourth, Prek Te, which arises in the Volcanic Uplands, has most of its length above 500 masl.

Table 5-9: Significance groups for physical characteristics of medium tributaries from Bolevan Plateau, Kontum Massif and Volcanic Uplands

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
79	HUAI TOMO	2,611	BP	3,719	2	2	2	1		1	1	2	1	1	1	1	
92	PREK PREAH	2,400	KM	3,964	2	2	3	1		1	1	2	2	1			
96	PREK KRIENG	3,332	KM	3,968	3	3	2	1		1	1	3	2	1			
99	PREK KAMP	1,142	KM	4,020	1	1	2	1		1	1	3	2	1			
100	PREK TE	4,364	VU	4,040	3	2	1	2		1	2	3	1	2	3		

In summary, Huai Tomo stands out because it is the only river that flows from the Bolevan Plateau directly into the Mekong (other sub-tributaries flow into the Se Kong). Prek Te stands out as different from the other 4P rivers because it arises at higher elevations in the Volcanic Uplands.

5.1.2.5 Tonle Sap basin

The medium sized tributaries in Cambodia, include the O Talas, that flows into the Mekong just above Stung Treng and others which flow into the Tonle Sap from the northern plains and from the Cardamon mountains. The Tonle Sap itself is considered as a catchment in its own right, and therefore stands out with distinct physical characteristics. The rivers flowing into the Tonle Sap from the north tend to be longer and have the highest stream densities of all the medium sized rivers, although the St. Battambang and St. Dauntri from the Cardamon mountains, are also long rivers. All of these rivers have higher proportions of their lengths in stream orders 3 and 4, and 5 and 6 than in orders 1 and 2. All the rivers have low slopes, apart from the St Battambang and St Dauntri, as is to be expected since they arise in the Cardamon mountains. These two rivers also arise at higher elevations, with St Battambang arising over 1,000 masl, and both having significant proportions of their lengths over 500 masl.

Table 5-10: Significance groups for physical characteristics of medium tributaries around Tonle Sap

Code	Tributary	Catchment area	Geological zone	Distance of confluence from	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
85	O TALAS	1,448	NTS	3,864	1	1	1	2		1	1	1	2	1			
88	ST.CHIKRENG	2,714	NTS	TS	2	3	1	3	2	1	1	3	3	1			
89	ST.SIEM REAP	3,619	NTS	TS	3	3	1	2		1	1	3	2	1			
90	ST.STAUNG	4,357	NTS	TS	3	3	1	2	2	1	1	3	3	1			
93	ST.SANGKER	2,344	CM	TS	1	2	1	1	3	1	1	3	3	1			
94	ST.BATTAMBANG	3,708	CM	TS	3	3	1	1		2	2	3	1	2	3	1	
95	TONLE SAP	2,744	TS	4,263	1	2	1	1	3	1	1	1	3				
97	ST.DAUNTRI	3,696	CM	TS	3	2	1	3		2	1	3	1	1	3		

In summary, the medium sized tributaries in Cambodia, can be grouped into the O Talas flowing directly into the Mekong, the northern plain rivers, and those that arise in the Cardamon mountains. Of the northern plain rivers, there is no one that stands out as being significantly different. Of the Cardamon mountain rivers, the St. Battambang stands out as different in view of its elevation followed by the St. Dauntri.

5.1.3 Small catchments

5.1.3.1 Northern Highlands

Many of the small catchments in the Northern Highlands do not have a distinct confluence with the Mekong, but rather a series of small first and second order streams that flow into the mainstream. Of those that do have a distinct confluence (Nam Keung, Doi Luang Pae Muang, Nam Ngam, Nam Mae Ngao and NamTon) the Doi Luang Pae Muang and Nam Ton a somewhat longer with a higher stream density than the others. The majority of these small tributaries have most of their lengths in stream orders 1 and 2, and the Nam Ngam , Nam Nhah, Nam Thong and H. Sophay have the highest slopes. Nam Thong and H. Sophay have the highest stream densities of this group. Most of these small tributaries have most of their length in the 100 to 500 masl elevations, although the Nam Keung, Nam Ngam and Nam Thong stand out as having significant proportions of their lengths between 500 and 1,000 masl.

Table 5-11: Significance groups for physical characteristics of small tributaries in Northern Highlands

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
9	B.KHAI SAN	778	NH		1	1	1	3	3		1	1		3			
10	NAM KEUNG	633	NH	2,099	1	1	3			1		1		1	2		
13	DOI LUANG PAE MUANG	688	NH	2,116	2	3	2	1		1	1	2		3			
14	NAM NGAM	489	NH	2,142	1	2	2	1		3	1	1		1	3	1	
17	NAM MAE NGAO	485	NH	2,188	1	1	3			2	1	1		1	1		
30	NAM NHAH	316	NH		1	1	3			3	1	2		1	1		
33	MUANG LIEP	488	NH		1	1	3			2	1	1		3			
34	NAM TON	587	NH	2,903	2	1	3			1		2		3			
36	NAM THONG	455	NH		2	3	2	1		3	1	3		1	2		
40	NAM PHONE	664	NH		1	1	3			2	1	1		3			
41	B.NAM SONG	138	NH		1	1	3					1		3			
43	H.SOPHAY	186	NH		1	2	1	2		3	1	3		1	1		
45	PHU LUONG YOT HUAI DUA	491	NH		1	1	1	3		1	1	1		3			
46	NAM KAI	602	NH		1	1	2	1		2	1	1		3			
49	H.MA HIAO	990	NH		2	2	2	1		2	1	1		3			

Many of the small tributaries in the Northern Highlands do not have distinct confluences with the Mekong except for the Nam Keung, Doi Luang Pae Muang, Nam Ngam, Nam Mae Ngao and NamTon. The Nam Keung, Nam Ngam, Nam Thong stand out as having a wider elevation range.

5.1.3.2 Khorat Plateau

The small rivers flowing from the Khorat Plateau and Loei Petchuan Fold Belt, also have relatively few distinct confluences with the Mekong. The longest rivers are the Huai Bang Haak and Huai Muk. Most have most of their lengths as stream orders 1 and 2, and the rivers with the highest slopes of 2nd order streams are the Huai Bang Haak, Huai Muk and Prek Mun. The Prek Mun flows off the south eastern escarpment of the Khorat Plateau into the Mekong near Khone Falls. The rivers with the highest stream density is the Prek Mun, most of the other small tributaries have middle range stream density. All of the small tributaries flow in the 100 to 500 masl elevation range, except for Prek Mun, which starts at this level and has most of its range below 100 masl.

Table 5-12: Significance groups for physical characteristics of small tributaries in Khorat Plateau and Loei Petchuan Fold Belt

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
53	PHU PA HUAK	132	LFB		1	1	2	1		2		2		3			
56	H. KHOK	538	LFB		2	2	3			1	1	2		3			
62	HUAI THUAI	739	KP	3,289	2	2	3			1	1	2		3			
63	HUAI HO	691	KP		2	2	3			1	1	2		3			
65	HUAI BANG HAAK	938	KP		3	3	2	1		1	3	1		3			
69	HUAI MUK	792	KP	3,410	3	3	1	3		1	3	2		3			
84	PREK MUN	476	KP		2	3	1	2		1	3	3	3	1			

In summary, the Huai Thuai and Huai Muk are the only small tributaries that have a disctinct confluence with the Mekong. The Prek Mun river stands out as being different from the other small tributaries from the Khorat Plateau, with higher 2nd order stream slopes, stream density and most of its flow occurring at elevations below 100 m.

5.1.3.3 Annamites

The small tributaries arising in the Annamite region have one that has a distinct confluence with the Mekong – the Nam Thon, and this is distinct in that it is a relatively long river with the highest stream density and with a wider spread of stream orders, most lying in the 3rd and 4th range. It has a medium range slope for 1st order streams which is higher than the others, which have relatively shallow slopes. The Nam Thon also arises between 500 and 1,000 masl, whilst all the others arise between 100 and 500 masl.

Table 5-13: Significance groups for physical characteristics of small tributaries in Annamite mountains

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
37	NAM KADUN	456	AMR		1	1	3			1	1	2		3			
44	NAM THON	838	AMR	3,205	3	3	1	2	1	2	1	3		1	1		
52	HOAAG HUA	626	AMR		2	2	3			1	1	2		3			
61	NAM MANG NGAI	944	AMR		3	2	3			1	1	1		3			

In summary the one small tributary arising from the Annamite region that stands out is the Nam Thon, which has a distinct confluence and arises at a higher elevation with a steeper slope than the rest.

5.1.3.4 Central Highlands, Bolevan and Volcanic uplands

There is only one small river that arises from volcanic geology, and that is the Huai Bang Lieng that flows off the Bolevan Plateau. It has a high length for its size and this is reflected in its high stream density. It has very high slopes for both 1st and 2nd order streams, and has a wide range of elevation spread, arising between 1,000 and 1,500 m, with significant proportions of its length at elevations between 500 to 1,500 masl and below 100 masl.

Table 5-14: Significance groups for physical characteristics of small tributaries from Bolevan Plateau

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
					Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km		km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
78	HUAI BANG LIENG	695	BP	3,699	3	2	1	2		3	3	3	2	1	2	2	

In summary, the Huai Bang Lieng appears to be a significant small tributary, because of its origin, length and stream density, slope and elevation range. These features distinguish it from other small tributaries to the north and south and from the Khorat Plateau.

5.1.3.5 Tonle Sap basin and Delta

There are no tributaries with small sized catchments in the Tonle Sap basin

5.2 Climate

The current climate attributes considered here are average annual rainfall and temperature, with the measure being the proportion of the catchment area in *very dry, dry, wet* and *very wet* zones, and *cool, warm* and *hot* zones.

5.2.1 Large tributaries

The very large tributaries generally fall into the dry zone, with only the Nam Ngum and Nam Cadinh falling into wet and very wet zones. The Nam Songkhram, Se Kong and Se San all have some significant proportions lying in the wet zones.

In terms of temperature, Nam Ou, Se Kong, Se San, Sre Pok and Siem Bok all have significant proportions of the catchment in the cool zones. Most of the Large tributaries in the Northern Highlands lie in the warm zone. There is an obvious transition to the hot zone with lower elevation and distance downstream, so that the large tributaries around the Tonle Sap and Delta all lie in the hot zone.

Table 5-15: Significance groupings of large catchments for rainfall and temperature

Code	Tributary	Catchment area	Geological zone	% of catchment area with Rainfall				% of catchment area with mean annual temperatures		
		sq km		<500 mm	500 - 1500 mm	1500-2500 mm	>3000 mm	<=22 deg C	22-25 deg C	25->27 deg C
				Very dry	Dry	Wet	Very wet	Cool	Warm	Hot
1	NAM OU	26,033	NH		1	1		3	2	
3	NAM THA	8,918	NH		3			1	3	
5	NAM MAE KOK	10,701	NH		2				3	
6	NAM SUONG	6,578	NH		3				3	
15	NAM KHAN	7,490	NH		3				3	
16	NAM MAE ING	7,267	NH		3				3	
24	NAM NGUM	16,906	NH		1	3	1		2	1
29	NAM CADINH	14,822	AMR		1	3	1		2	1
42	NAM SONGKHRAM	13,123	KP		1	2			2	2
59	SE BANG FAI	10,407	AMR		1	1			2	1
60	NAM CHI	49,133	KP	1	1				2	2
66	SE BANG HIENG	19,958	AMR		1					3
71	SE KONG	28,815	KM		1	2		3	2	1
72	NAM MUN	70,574	KP	1	1	1		1	1	2
74	SE DONE	7,229	AMR		1	1			1	2
77	SE SAN	18,888	KM		1	2		3	1	1
81	ST.SRENG	9,986	NTS		3					3
82	ST. SEN	16,360	NTS		3					3
83	ST.MONGKOL BOREY	14,966	NTS		3					3
86	SRE POK	30,942	KM		2			3	2	1
87	SIEM BOK	8,851	NTS		1	1		3	2	1
91	ST.CHINIT	8,237	NTS		3					3
98	ST.PURSAT	5,965	CM		3					3
101	ST.BARIBO	7,154	CM		3					3
102	PREK CHHLONG	5,957	VU		3					2
103	DELTA	48,235	D		3					3
104	PREK THNOT	6,124	CM		3					3

5.2.2 Medium Tributaries

The rainfall pattern for the medium sized tributaries is much the same, with almost all the tributaries lying in the dry zone, except for Nam Mang, Nam Nhiep, H. Bang Bot and Nam Hinboun.

The temperature patterns for the medium sized tributaries, show that most of the tributaries in the Norhern Highlands lie in the warm zone, apart from the Nam Nuao. In the Khorat Plateau and Loei Petchuan Fold belt, most lie in the hot zone, as in the tributaries around the Tonle Sap. Other tributaries further south that have a significant proportion of their catchments in the cool zones, these are ones that originate from higher slopes on the Bolevan Plateau (Huai Tomo), the Tonle Repon and Stung Chikreng from the hills bordering the Khorat Plateau, and the 4P rivers (Prek Kamp, Prek Krieng Prek Preah, Prek Te) that flow into the Mekong from the east just south of the 3S rivers.

Table 5-16: Significance groupings of medium catchments for rainfall and temperature

Code	Tributary	Catchment area	Geological zone	% of catchment area with Rainfall				% of catchment area with mean annual temperatures		
		sq km		<500 mm	500 - 1500 mm	1500-2500 mm	>3000 mm	<=22 deg C	22-25 deg C	25->27 deg C
				Very dry	Dry	Wet	Very wet	cool	warm	Hot
2	NAM NUAO	2,287	NH		3			3	2	
4	NAM MA	1,141	NH		3				3	
7	NAM PHO	2,855	NH		3				3	
8	NAM MAE KHAM	4,079	NH		1				3	
11	NAM NGAOU	1,495	NH		3				3	
12	NAM BENG	2,131	NH		3				3	
18	NAM KHOP	1,521	NH		3				3	
19	NAM TAM	1,548	NH		3				3	
20	NAM NAGO	1,008	NH		3				3	
21	NAM SING	2,681	NH		3				3	
22	NAM PHUONG	4,139	NH		1	1			2	1
23	NAM NGEUN	1,819	NH		3				3	
25	NAM HOUNG	2,872	NH		3				3	
26	NAM NHIEP	4,577	NH		1	1	2		1	2
27	NAM PHOUL	2,095	NH		3				3	
28	NAM SANE	2,226	NH			2	1			3
31	NAM NHIAM	1,990	NH		3				3	
32	NAM MANG	1,836	NH			2	3			3
35	NAM SANG	1,290	NH		3					3
38	H.BANG BOT	2,402	KP		1	3	1		1	2
39	NAM MI	1,032	NH		3				2	1
47	NAM HINBOUN	2,529	AMR			3			3	
48	H.NAM HUAI	1,755	KP		3				2	2
50	NAM HEUNG	4,901	LFB		3				2	1
51	HUAI NAM SOM	1,072	LFB		3					3
54	HUAI LUANG	4,090	LFB		1	1				3
55	HUAI MONG	2,700	LFB		3					3
57	NAM SUAI	1,247	LFB		3					3
58	NAM LOEI	4,012	LFB		3				2	1
64	NAM KAM	3,495	KP		3					3
67	HUAI SOM PAK	2,516	AMR		3					3
68	HUAI BANG SAI	1,367	KP		3					3
70	HUAI BANG I	1,496	KP		3					3
73	H.BANG KOI	3,313	KP		3					3
75	SE BANG NOUAN	3,048	AMR		3				1	3
76	HUAI KHAMOUAN	3,762	KP		3			3	1	1
79	HUAI TOMO	2,611	BP		3			3	1	1
80	TONLE REPON	2,379	KP		1	1		3	1	
85	O TALAS	1,448	NTS		1	2		2	2	2
88	ST.CHIKRENG	2,714	NTS		3			3	1	2
89	ST.SIEM REAP	3,619	NTS		3					3
90	ST.STAUNG	4,357	NTS		3					3
92	PREK PREAH	2,400	KM		3			3	2	1
93	ST.SANGKER	2,344	CM		1	1		2	2	2
94	ST.BATTAMBANG	3,708	CM		3					3
95	TONLE SAP	2,744	TS		3					3
96	PREK KRIENG	3,332	KM		3			3	1	1
97	ST.DAUNTRI	3,696	CM		1					3
99	PREK KAMP	1,142	KM		3			3	2	1
100	PREK TE	4,364	VU		3			3	2	2

5.2.3 Small tributaries

Of the small tributaries, most from the Northern Highlands and Khorat Plateau lie in the dry zone, although those originating in the Annamites have noticeably more in the wet zone. With regard to temperature, the majority of small tributaries in the Northern Highlands lie in the warm zone, although some of the lower lying tributaries, such as Nam Ton, Nam Thong, Nam Kadun, Huai Sophay, H.Ma Hiao, and those of the Loei Petchbuan belt fold and Khorat Plataeu such as Phu Pa Huak, H. Khok and Huai Ho and Huai Muk lie significantly in the hot zone.

Table 5-17: Significance groupings of small catchments for rainfall and temperature

Code	Tributary	Catchment area	Geological zone	% of catchment area with Rainfall				% of catchment area with mean annual temperatures		
		sq km		<500 mm	500 - 1500 mm	1500- 2500 mm	>3000 mm	<=22 deg C	22-25 deg C	25->27 deg C
				Very dry	Dry	Wet	Very wet	cool	warm	Hot
9	B.KHAI SAN	778	NH		3				3	
10	NAM KEUNG	633	NH		3				3	
13	DOI LUANG PAE MUANG	688	NH		3				3	
14	NAM NGAM	489	NH		3				3	
17	NAM MAE NGAO	485	NH		3				3	
30	NAM NHAH	316	NH		3				3	
33	MUANG LIEP	488	NH		3				3	
34	NAM TON	587	NH		1	1				3
36	NAM THONG	455	NH			1	3			3
37	NAM KADUN	456	AMR			2	2			3
40	NAM PHONE	664	NH		3				3	
41	B.NAM SONG	138	NH		3				3	
43	H.SOPHAY	186	NH			3				3
44	NAM THON	838	AMR			3			2	2
45	PHU LUONG YOT HUAI DUA	491	NH		3	1			1	2
46	NAM KAI	602	NH		3	1			3	
49	H.MA HIAO	990	NH		1	1				3
52	HOAAG HUA	626	AMR			3			3	
53	PHU PA HUAK	132	LFB		3					3
56	H. KHOK	538	LFB		3					3
61	NAM MANG NGAI	944	AMR		1	2			2	1
62	HUAI THUAI	739	KP		1	2			1	2
63	HUAI HO	691	KP		1	2				3
65	HUAI BANG HAAK	938	KP		3				1	2
69	HUAI MUK	792	KP		3					3
78	HUAI BANG LIENG	695	BP		3			1	1	2
84	PREK MUN	476	KP		1	1		1	2	1

5.3 Geological attributes

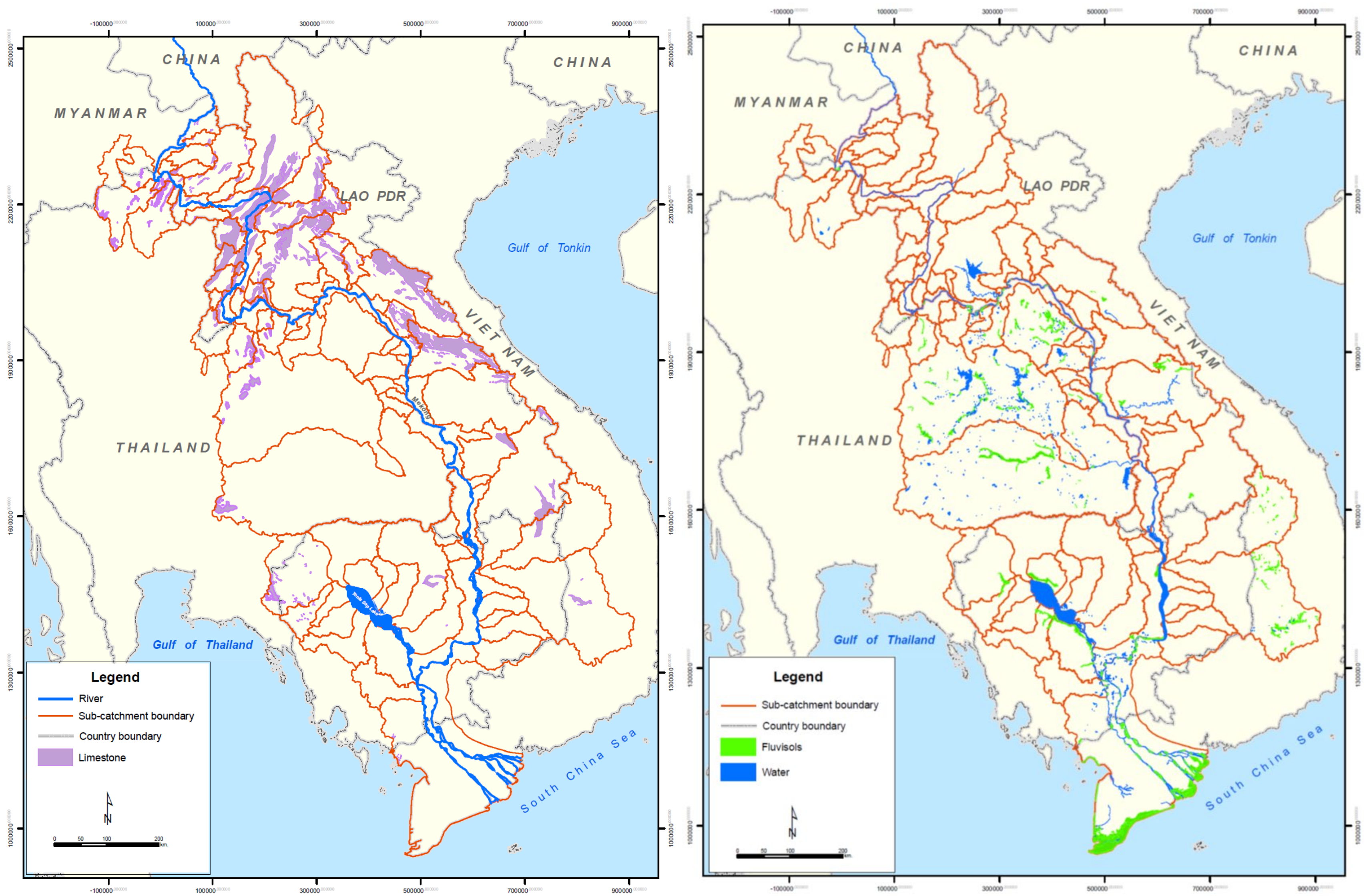
Two geological aspects are considered in this section:

- the presence of limestone in the catchment, and the proportion of limestone within the whole of the LMB
- the presence of floodplains as measured by the combined presence of fluvisols and floodplain wetlands

The distributions of limestone and fluvisols in the LMB overlaid by the catchment boundaries is shown in Figure 5.1

The presence of karst and caves in the tributaries has been identified as important ecological determinants.

Figure 5-1: Distribution of limestone and fluvisols in the LMB



5.3.1 Large tributaries

5.3.1.1 Limestone

Of the large tributaries, the Nam Suong and Nam Khan in the Northern Highlands and the Nam Cadinh and Se Bang Fai in the Annamites have the highest proportion of limestone in the catchments, followed by Nam Ou, Nam Tha, Nam Mae Ing, Nam Ngum in the Northern Highlands, and the Se Kong and the Stung Mongkol Borey.

The large tributaries which have the highest proportion of limestone in the whole of the LMB include the Nam Ngum, Nam Cadinh and Se Bang Fai. Other large tributaries, not previously mentioned, that have high limestone include Nam Mun and Nam Chi and the Se Done.

The large tributaries that have known karst features and caves include Nam Ou, Nam Tha, Nam Khan, Nam Ngum, Nam Cadinh and the Se Bang Fai.

5.3.1.2 Floodplains

None of the large tributaries of the Northern highlands have floodplain areas apart from the Nam Ngum which has a relatively low proportion of floodplain. In the Khorat Plateau and this is comparatively small, the large tributaries with significant floodplains include the Nam Chi, Siem Bok and, of course, the Delta. Most of the other more southern large tributaries have medium proportions of floodplain areas, apart from the Nam Cadinh, Se Kong and Se San which have low proportions of floodplain areas.

Table 5-18: Significance groupings of limestone and floodplains in large tributaries

Code	Tributary	Catchment area	Geological zone	Percentage of limestone		Presence of karst and caves	Percentage of fluvisols		Fluvisols + floodplain wetlands
				in catchment	in LMB		in catchment	in LMB	in catchment
		sq km		%	%		%	%	%
1	NAM OU	26,033	NH	2	2				-
3	NAM THA	8,918	NH	2	1				-
5	NAM MAE KOK	10,701	NH	1	1				-
6	NAM SUONG	6,578	NH	3	2				-
15	NAM KHAN	7,490	NH	3	2				-
16	NAM MAE ING	7,267	NH	2	1				-
24	NAM NGUM	16,906	NH	2	3				1
29	NAM CADINH	14,822	AMR	3	3		1	1	1
42	NAM SONGKHRAM	13,123	KP	-	-		3	3	3
59	SE BANG FAI	10,407	AMR	3	3		1	1	2
60	NAM CHI	49,133	KP	1	2		1	3	3
66	SE BANG HIENG	19,958	AMR	1	1		2	2	2
71	SE KONG	28,815	KM	2	2		1	1	1
72	NAM MUN	70,574	KP	1	2		2	3	2
74	SE DONE	7,229	AMR	1	2			-	2
77	SE SAN	18,888	KM	1	1		1	1	1
81	ST.SRENG	9,986	NTS	-	-			-	2
82	ST. SEN	16,360	NTS	1	1			-	2
83	ST.MONGKOL BOREY	14,966	NTS	2	2		1	2	2
86	SRE POK	30,942	KM	1	1		2	3	2
87	SIEM BOK	8,851	NTS	-	-		2	2	3
91	ST.CHINIT	8,237	NTS	1	1		1	1	2
98	ST.PURSAT	5,965	CM	-	-		2	2	2
101	ST.BARIBO	7,154	CM	-	-		3	2	2
102	PREK CHHLONG	5,957	VU	1	1		1	1	2
103	DELTA	48,235	D	1	1		3	3	3
104	PREK THNOT	6,124	CM	-	-		1	1	2

5.3.2 Medium tributaries

5.3.2.1 Limestone

Of the medium-sized tributaries, the Nam Sing, Nam Houng, Nam Phoul and Nam Sang in the Northern Highlands, the Nam Hinboun in the Annamite region stand out as having the highest proportions of limestone in the catchment, followed by Nam Ma, Nam Ngaou, Nam Tam, Nam Phuong, Nam Nhiep, Nam Sane and Nam Nhiam. The Nam Loei in the Loei Petchuan Fold Belt also has a medium range of limestone in the catchment.

When considering the contribution to limestone in the overall LMB, the Nam Sing, Nam Phuong, Nam Houng, Nam Nhiep, Nam Phoul and Nam Hinboun are significant.

The medium tributaries which have karst features and caves include the Nam Beng, Nam Ngeun, Nam Sing and Nam Hinboun.

5.3.2.2 Floodplains

As with the large tributaries, the medium tributaries in the Northern Highlands generally have relatively small or no floodplain areas. Those medium sized tributaries that have significant floodplain areas include the H. Nam Huai, Nam Heung, Huai Nam Som, Huai Mong, the Nam Loei, Nam Kam, Huai Bang Sai, Huai Bang I, Huai Bang Koi all from the Khorat Plateau or LFB in North East Thailand. Further south the tributaries feeding into the Tonle Sap such as the St. Chikreng, St. Siem Reap, St. Staung, and the Tonle Sap itself all have significant flood plain areas in their catchments. The Stung Battambang has a high proportion of fluvisols but less when combined with floodplain wetland areas.

Table 5-19: Significance groupings of limestone and floodplains in medium tributaries

Code	Tributary	Catchment area	Geological zone	Percentage of limestone		Presence of karst and caves	Percentage of fluvisols		Fluvisols and floodplain wetlands
				in catchment	in LMB		in catchment	in LMB	in catchment
		sq km		%	%		%	%	%
2	NAM NUAO	2,287	NH	2	1				1
4	NAM MA	1,141	NH	2	1				
7	NAM PHO	2,855	NH	1	1				
8	NAM MAE KHAM	4,079	NH	1	1				
11	NAM NGAOU	1,495	NH	2	1				
12	NAM BENG	2,131	NH	1	2				
18	NAM KHOP	1,521	NH	1	2				
19	NAM TAM	1,548	NH	2	2				
20	NAM NAGO	1,008	NH	1	1				
21	NAM SING	2,681	NH	3	3				
22	NAM PHUONG	4,139	NH	2	3				1
23	NAM NGEUN	1,819	NH	1	1				
25	NAM HOUNG	2,872	NH	3	3				
26	NAM NHIEP	4,577	NH	2	3				1
27	NAM PHOUL	2,095	NH	3	3				
28	NAM SANE	2,226	NH	2	2				
31	NAM NHIAM	1,990	NH	2	2				
32	NAM MANG	1,836	NH						1
35	NAM SANG	1,290	NH	3	2				1
38	H.BANG BOT	2,402	KP				2	3	2
39	NAM MI	1,032	NH	1	1			-	
47	NAM HINBOUN	2,529	AMR	3	3			-	
48	H.NAM HUAI	1,755	KP	1	1		1	1	3
50	NAM HEUNG	4,901	LFB	1	2		1	1	3
51	HUAI NAM SOM	1,072	LFB	1	1				3
54	HUAI LUANG	4,090	LFB				2	3	2
55	HUAI MONG	2,700	LFB	1	1		2	1	3
57	NAM SUAI	1,247	LFB				1	1	2
58	NAM LOEI	4,012	LFB	2	2		2	3	3
64	NAM KAM	3,495	KP				1	1	3
67	HUAI SOM PAK	2,516	AMR				2	3	1
68	HUAI BANG SAI	1,367	KP					-	3
70	HUAI BANG I	1,496	KP				2	1	3
73	H.BANG KOI	3,313	KP				1	1	3
75	SE BANG NOUAN	3,048	AMR					-	2
76	HUAI KHAMOUAN	3,762	KP					-	2
79	HUAI TOMO	2,611	BP					-	2
80	TONLE REPON	2,379	KP					-	2
85	O TALAS	1,448	NTS					-	1
88	ST.CHIKRENG	2,714	NTS					-	3
89	ST.SIEM REAP	3,619	NTS				3	3	3
90	ST.STAUNG	4,357	NTS					-	3
92	PREK PREAH	2,400	KM				1	1	2
93	ST.SANGKER	2,344	CM					-	3
94	ST.BATTAMBANG	3,708	CM	1	1		3	3	2
95	TONLE SAP	2,744	TS					-	3
96	PREK KRIENG	3,332	KM					-	2
97	ST.DAUNTRI	3,696	CM				1	1	2
99	PREK KAMP	1,142	KM					-	1
100	PREK TE	4,364	VU	1	2			-	1

5.3.3 Small tributaries

5.3.3.1 Limestone

Of the small tributaries, only the Nam Nhah, and the B. Nam Song have significant proportions of limestone in their catchments and the first makes a significant contribution to limestone in the LMB, followed by Muang Liep, Nam Ton, Phu Luong Yot Huai Dua, and Nam Kai in the Northern Highlands with medium proportion of limestone in the catchment. In the Annamites, the Nam Mang Ngai has a medium proportion of limestone in the catchment, but makes a significant contribution to limestone in the LMB.

5.3.3.2 Floodplains

The Phu Pa Huak in the LFB has significant floodplain and wetland areas, together with Huai Thuai, Huai Ho and Huai Muk on the Khorat Plateau. Those small tributaries with a medium proportion of floodplain wetlands include H. Ma Hiao (around Vientiane), H. Khok, Huai Bang Haak and Prek Mun.

Table 5-20: Significance groupings of limestone and floodplains in small tributaries

Code	Tributary	Catchment area	Geological zone	Percentage of limestone		Percentage of fluvisols		floodplain wetlands
				in catchment	in LMB	in catchment	in LMB	in catchment
		sq km		%	%	%	%	%
9	B.KHAI SAN	778	NH			2	3	2
10	NAM KEUNG	633	NH	1	1			
13	DOI LUANG PAE MUANG	688	NH	1	1			
14	NAM NGAM	489	NH	1	1			
17	NAM MAE NGAO	485	NH	1	1			
30	NAM NHAH	316	NH	3	3			
33	MUANG LIEP	488	NH	2	2			
34	NAM TON	587	NH	2	2			1
36	NAM THONG	455	NH			1	1	
37	NAM KADUN	456	AMR					2
40	NAM PHONE	664	NH	1	1			
41	B.NAM SONG	138	NH	3	1			1
43	H.SOPHAY	186	NH					1
44	NAM THON	838	AMR					
45	PHU LUONG YOT HUAI DUA	491	NH	2	2	1	1	1
46	NAM KAI	602	NH	2	2			
49	H.MA HIAO	990	NH			1	0	2
52	HOAAG HUA	626	AMR					
53	PHU PA HUAK	132	LFB			3	3	3
56	H. KHOK	538	LFB			2	3	2
61	NAM MANG NGAI	944	AMR	2	3			1
62	HUAI THUAI	739	KP					3
63	HUAI HO	691	KP			1	1	3
65	HUAI BANG HAAK	938	KP			2	3	2
69	HUAI MUK	792	KP					3
78	HUAI BANG LIENG	695	BP					1
84	PREK MUN	476	KP					2

6 Assessing ecological indicators

In this chapter, the significance each of the tributaries has been assessed by its ecological diversity and uniqueness as measured by the length of river lying within different ecological zones, by the recognized biodiversity importance from terrestrial protected areas and key biodiversity areas within the catchment, and by the presence of wetlands within the catchments. Also featured under wetlands is the presence of internationally important Ramsar wetlands and regionally important wetlands identified by the MRC. In addition, a section on the connectivity of the Mekong and its tributaries has been excerpted from a paper prepared by Bernhard Lehner et al. [4]

6.1 Ecological zone uniqueness and diversity

In this section, the tributaries are assessed for a) those that have the highest proportion of ecological zones that they pass through, as shown by the index of ecological zone diversity, where a High scale (3) on the index shows the greatest ecological zone diversity, and b) those that have restricted ecological zones that they pass through and are therefore more unique. Thus ecological uniqueness is indicated by the higher scales (3) of the % of river length in one or two ecological zones. The overlay of catchment boundaries with the ecological zones is shown in Figure 6-1.

6.1.1 Large tributaries

Of the large tributaries, those with the highest ecological zone diversity include:

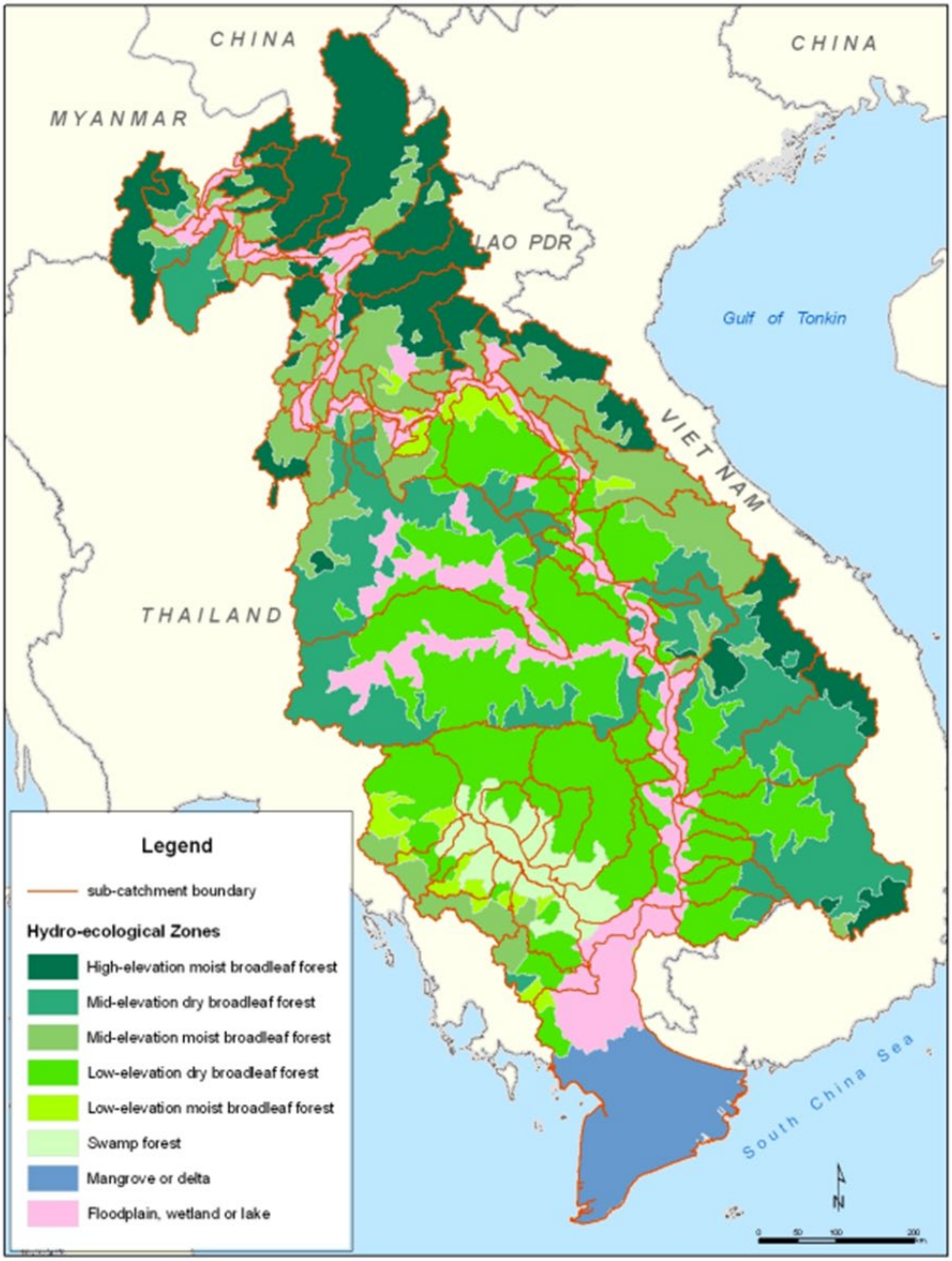
- Nam Ngum for the Northern Highlands,
- Nam Chi stands out for the Khorat Plateau,
- Se Kong and Sre Pok stand out for the Central Highlands and
- Stung Baribo and Prek Thnot for the Cardamon mountains.

The tributaries which have a low ecological zone diversity (1) and high proportion of their catchment area in one of the ecological zones include:

- **High elevation moist broadleaf forest** – Nam Ou, Nam Tha, Nam Suong and Nam Khan (Northern Highlands)
- **Mid elevation moist broadleaf forest** – Nam Cadinh and the Se Bang Fai in the Annamites
- **Mid elevation dry broadleaf forest** – Nam Mae Ing in Northern Highlands and Se San in Central Highlands
- **Low elevation moist broadleaf forest** – no rivers have low zone diversity and high proportion in this catchment, though Nam Songkhram, Stung Mongkol Borey and Stung Pursat have medium ecological zone diversity and high proportions of their catchment area in this ecological zone.
- **Low elevation dry broadleaf forest** – Stung Sreng, Stung Sen, Stung Chinit, arising in the northern plains of Cambodia and flowing into the Tonle Sap, and Prek Chhlong from the Volcanic uplands.

[4] Bernhard Lehner, Günther Grill, Camille Ouellet Dallaire, Etienne Fluet-Chouinard (2011) Ecosystem fragmentation and flow regulation in the Mekong River Basin due to past and future dam development: a pilot study. Paper prepared for WWF greater Mekong.

Figure 6-1: Overlay of catchment boundaries with the ecological zones



- **Floodplain, wetlands and lakes –** Siem Bok is the only catchment with low ecological diversity and high proportion of its catchment in this ecological zone.
- **Swamp forest –** is represented by the tributaries that flow into the Tonle Sap, especially Stung Sreng, Stung Sen and Stung Chinit.
- **Mangrove or delta –** is only represented by the Delta catchment.

Table 6-1: Significance groupings for ecological zone diversity in large tributaries

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length (all stream orders)	% of river length in each ecological zone								Ecological zone diversity index
		sq km			Length	High-elevation moist broadleaf forest	Mid-elevation moist broadleaf forest	Mid-elevation dry broadleaf forest	Low-elevation moist broadleaf forest	Low-elevation dry broadleaf forest	Floodplain wetland or lake	Swamp forest	Mangrove or delta	
				km	km									
1	NAM OU	26,033	NH	2,443	5,740	3	2	-	-	-	1	-	-	1
3	NAM THA	8,918	NH	2,203	1,029	3	2	-	-	-	1	-	-	1
5	NAM MAE KOK	10,701	NH	2,115	1,833	3	2	1	-	-	2	-	-	2
6	NAM SUONG	6,578	NH	2,453	1,070	3	1	-	-	-	-	-	-	1
15	NAM KHAN	7,490	NH	2,467	1,454	3	1	-	-	-	2	-	-	1
16	NAM MAE ING	7,267	NH	2,176	1,682	1	1	3	-	-	1	-	-	1
24	NAM NGUM	16,906	NH	3,039	3,365	2	3	-	1	-	2	-	-	3
29	NAM CADINH	14,822	AMR	3,173	2,981	2	3	-	1	-	-	-	-	1
42	NAM SONGKHRAM	13,123	KP	3,265	2,759	-	-	1	3	3	2	-	-	2
59	SE BANG FAI	10,407	AMR	3,364	1,583	-	3	-	1	1	1	-	-	1
60	NAM CHI	49,133	KP	3,632	9,303	1	2	3	-	2	3	-	-	3
66	SE BANG HIENG	19,958	AMR	3,496	5,114	-	3	1	-	2	1	-	-	2
71	SE KONG	28,815	KM	3,901	4,932	2	2	1	-	2	2	-	-	3
72	NAM MUN	70,574	KP	3,632	12,192	-	-	1	-	2	3	-	-	2
74	SE DONE	7,229	AMR	3,677	2,249	1	2	3	-	1	1	-	-	2
77	SE SAN	18,888	KM	3,900	2,785	2	-	3	-	2	-	-	-	1
81	ST.SRENG	9,986	NTS	TS	2,091	-	-	-	-	3	-	2	-	1
82	ST. SEN	16,360	NTS	TS	3,182	-	-	-	-	3	-	2	-	1
83	ST.MONGKOL BOREY	14,966	NTS	TS	3,171	-	2	-	3	2	-	1	-	2
86	SRE POK	30,942	KM	3,900	6,729	1	1	3	-	1	2	-	-	3
87	SIEM BOK	8,851	NTS		2,258	-	-	-	-	2	3	1	-	1
91	ST.CHINIT	8,237	NTS	TS	1,748	-	-	-	-	3	2	2	-	1
98	ST.PURSAT	5,965	CM	TS	1,597	-	3	-	3	1	-	2	-	2
101	ST.BARIBO	7,154	CM	TS	2,192	-	2	-	3	2	2	2	-	3
102	PREK CHHLONG	5,957	VU	4,077	1,713	-	-	1	-	3	2	-	-	1
103	DELTA	48,235	D	4,313	5,467	-	-	-	1	1	3	-	3	2
104	PREK THNOT	6,124	CM	4,285	1,740	-	2	1	3	2	3	-	-	3

6.1.2 Medium tributaries

Of the medium sized tributaries, those with the highest ecological zone diversity index include:

- Nam Mae Kham in the Northern areas
- H. Bang Bot and H Bang Koi in the Khorat Plateau and Nam Heung and Huai Mong in the LFB
- Se Bang Nouan in the Annamites
- Stung Sangker and Stung Battambang from the Cardamon Mountains
- Prek Krieng and Prek Te from the Central Highlands and Volcanic Uplands

In terms of uniqueness,

- **High elevation moist broadleaf forest** – Nam Nuao, Nam Ma, Nam Pho, Nam Ngaou, Nam Beng and Nam Nago (Northern Highlands)
- **Mid elevation moist broadleaf forest** – Nam Nhiam Nam Sang and Nam Mi in Northern Highlands, Nam Hinboun in the Annamites and Huai Nam Som in the LFB.

- **Mid elevation dry broadleaf forest** – Huai Nam Som in the LFB, Huai Bang San and Huai Bang I in the Khorat Plateau
- **Low elevation moist broadleaf forest** – Nam Suai in LFB, and Stung Dauntri from the Cardamon mountains
- **Low elevation dry broadleaf forest** – Huai Bang I from Khorat Plateau, Tonle Repon, O Talas and Stung Chikreng from northern plains of Cambodia, Prek Preah and Prek Kamp from Central Highlands
- **Floodplain, wetlands and lakes** – Nam Khop, Nam Tam, Nam Nago and Nam Sing have significant floodplain areas in the medium rivers of the Northern Highlands, as does Huai Tomo from Bolevan Plateau and Prek Preah from Central highlands
- **Swamp forest –** is represented by the tributaries that flow into the Tonle Sap, especially Stung Siem Reap.
- **Mangrove or delta –** is not represented by any medium tributaries .

Table 6-2: Significance groupings for ecological zone diversity in medium tributaries

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length (all stream orders)	% of river length in each ecological zone								Ecological zone diversity index
		sq km			Length	High-elevation moist broadleaf forest	Mid-elevation moist broadleaf forest	Mid-elevation dry broadleaf forest	Low-elevation moist broadleaf forest	Low-elevation dry broadleaf forest	Floodplain wetland or lake	Swamp forest	Mangrove or delta	
				km	km									
2	NAM NUAO	2,287	NH	1,966	259	3	-	-	-	-	2	-	-	1
4	NAM MA	1,141	NH	1,998	110	3	2	-	-	-	2	-	-	1
7	NAM PHO	2,855	NH	2,005	395	3	2	-	-	-	1	-	-	1
8	NAM MAE KHAM	4,079	NH	2,112	1,046	3	2	1	-	-	2	-	-	3
11	NAM NGAOU	1,495	NH	2,154	193	3	2	-	-	-	1	-	-	1
12	NAM BENG	2,131	NH	2,307	176	3	-	-	-	-	-	-	-	1
18	NAM KHOP	1,521	NH		345	-	2	-	-	-	3	-	-	1
19	NAM TAM	1,548	NH		217	1	1	-	-	-	3	-	-	1
20	NAM NAGO	1,008	NH		220	3	2	-	-	-	3	-	-	1
21	NAM SING	2,681	NH		438	1	2	-	-	-	3	-	-	1
22	NAM PHUONG	4,139	NH		417	3	2	-	-	-	3	-	-	2
23	NAM NGEUN	1,819	NH	2,322	323	3	3	-	-	-	1	-	-	2
25	NAM HOUNG	2,872	NH		556	3	2	-	-	-	1	-	-	2
26	NAM NHIEP	4,577	NH	3,123	707	3	2	-	-	-	1	-	-	2
27	NAM PHOUL	2,095	NH	2,581	348	1	3	-	-	-	2	-	-	2
28	NAM SANE	2,226	NH	3,130	443	3	2	-	-	-	3	-	-	2
31	NAM NHIAM	1,990	NH	2,686	265	-	3	-	-	-	1	-	-	1
32	NAM MANG	1,836	NH	3,080	425	1	3	-	-	-	1	-	-	2
35	NAM SANG	1,290	NH	2,881	109	-	3	-	-	-	2	-	-	1
38	H.BANG BOT	2,402	KP	3,071	462	-	1	-	3	1	3	-	-	3
39	NAM MI	1,032	NH		83	-	3	-	-	-	1	-	-	1
47	NAM HINBOUN	2,529	AMR	3,282	421	-	3	-	1	-	1	-	-	1
48	H.NAM HUAI	1,755	KP		244	-	2	3	-	-	2	-	-	2
50	NAM HEUNG	4,901	LFB	2,778	1,106	3	3	-	-	-	1	-	-	3
51	HUAI NAM SOM	1,072	LFB	2,903	152	-	3	3	-	-	1	-	-	1
54	HUAI LUANG	4,090	LFB	3,023	830	-	2	-	-	1	1	-	-	1
55	HUAI MONG	2,700	LFB	2,952	545	-	2	3	-	-	2	-	-	3
57	NAM SUAI	1,247	LFB	3,014	277	-	-	-	3	-	2	-	-	1
58	NAM LOEI	4,012	LFB	2,789	639	-	3	3	-	-	1	-	-	2
64	NAM KAM	3,495	KP	3,366	754	-	-	3	-	3	2	-	-	2
67	HUAI SOM PAK	2,516	AMR		584	-	-	-	-	3	3	-	-	2
68	HUAI BANG SAI	1,367	KP	3,401	255	-	-	3	-	-	2	-	-	1
70	HUAI BANG I	1,496	KP	3,439	243	-	-	3	-	3	-	-	-	1
73	H.BANG KOI	3,313	KP		658	-	-	1	-	1	2	-	-	3
75	SE BANG NOUAN	3,048	AMR	3,517	870	-	-	3	-	1	2	-	-	3
76	HUAI KHAMOUAN	3,762	KP	3,750	618	-	-	3	-	1	2	-	-	2
79	HUAI TOMO	2,611	BP	3,719	615	-	-	1	-	1	3	-	-	1
80	TONLE REPON	2,379	KP	3,813	309	-	-	-	-	3	-	-	-	1
85	O TALAS	1,448	NTS	3,864	254	-	-	-	-	3	-	-	-	1
88	ST.CHIKRENG	2,714	NTS	TS	778	-	-	-	-	3	-	1	-	1
89	ST.SIEM REAP	3,619	NTS	TS	892	-	-	-	-	1	-	3	-	1
90	ST.STAUNG	4,357	NTS	TS	1,070	-	-	-	-	3	-	1	-	2
92	PREK PREAH	2,400	KM	3,964	463	-	-	-	-	3	3	-	-	1
93	ST.SANGKER	2,344	CM	TS	530	-	-	-	1	1	-	3	-	3
94	ST.BATTAMBANG	3,708	CM	TS	1,207	-	2	-	1	1	-	1	-	3
95	TONLE SAP	2,744	TS	4,263	325	-	-	-	1	-	-	3	-	2
96	PREK KRIENG	3,332	KM	3,968	911	-	-	1	-	3	2	-	-	3
97	ST.DAUNTRI	3,696	CM	TS	891	-	-	-	3	1	-	3	-	2
99	PREK KAMP	1,142	KM	4,020	309	-	-	-	-	3	1	-	-	1
100	PREK TE	4,364	VU	4,040	1,189	-	-	3	-	1	2	-	-	3

6.1.3 Small tributaries

The following small tributaries stand out as having a high ecological zone diversity index:

- Phu Luong Yot Huai Dua and Huai Ma Hiao in the Northern Highlands
- Nam Thon in the Annamites
- Huai Bang Haak and Huai Muk on the Khorat Plateau

In terms of uniqueness, the following small tributaries have a low ecological zone diversity index and high representation of these ecological zones:

- **High elevation moist broadleaf forest** – None of the small tributaries occur in this ecological zone
- **Mid elevation moist broadleaf forest** – Nam Nhah and Nam Phone in the Northern Highlands
- **Mid elevation dry broadleaf forest** – None of the small tributaries have a low ecological zone diversity index and a high representation in this ecological zone, although the Huai Bang Haak on the Khorat Plateau is the only small tributary with high respresentation in the mid-elevation dry broadleaf forest zone.
- **Low elevation moist broadleaf forest** – Huai Khok in LFB
- **Low elevation dry broadleaf forest** – There are no small tributaries with a low ecological zone index and high representation in the low elevation dry broadleaf forest zone, although the Huai Thuai and Huai Ho and Prek Mun all have medium ecological zone indices and high representation in this zone
- **Floodplain, wetlands and lakes** – Ban Khai San, Doi Luang Pae Muang and Ban Nam Song have significant floodplain areas in the small rivers of the Northern Highlands, as does Nam Kadun, Hoag Hua in the Annamites, and Phu Pa Huak in the Loei Petchuan Fold Belt.
- **Swamp forest –** is not represented by any small tributaries
- **Mangrove or delta –** is not represented by any small tributaries.

Table 6-3: Significance groupings for ecological zone diversity in small tributaries

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length (all stream orders)	% of river length in each ecological zone								Ecological zone diversity index
		sq km			Length	High-elevation moist broadleaf forest	Mid-elevation moist broadleaf forest	Mid-elevation dry broadleaf forest	Low-elevation moist broadleaf forest	Low-elevation dry broadleaf forest	Floodplain wetland or lake	Swamp forest	Mangrove or delta	
				km	km									
9	B.KHAI SAN	778	NH		73	-	1	-	-	-	3	-	-	1
10	NAM KEUNG	633	NH	2,099	52	-	2	-	-	-	1	-	-	1
13	DOI LUANG PAE MUANG	688	NH	2,116	125	-	-	-	-	-	3	-	-	1
14	NAM NGAM	489	NH	2,142	68	-	2	-	-	-	2	-	-	2
17	NAM MAE NGAO	485	NH	2,188	69	-	3	-	-	-	1	-	-	2
30	NAM NHAH	316	NH		63	-	3	-	-	-	1	-	-	1
33	MUANG LIEP	488	NH		66	-	2	-	-	-	1	-	-	1
34	NAM TON	587	NH	2,903	107	-	3	-	-	-	1	-	-	1
36	NAM THONG	455	NH		129	-	2	-	-	-	2	-	-	2
37	NAM KADUN	456	AMR		83	-	-	-	1	-	3	-	-	1
40	NAM PHONE	664	NH		101	-	3	-	-	-	1	-	-	1
41	B.NAM SONG	138	NH		4	-	-	-	-	-	3	-	-	1
43	H.SOPHAY	186	NH		85	-	1	-	1	-	2	-	-	2
44	NAM THON	838	AMR	3,205	243	-	3	-	-	-	1	-	-	3
45	PHU LUONG YOT HUAI DUA	491	NH		54	-	2	1	-	-	2	-	-	3
46	NAM KAI	602	NH		71	-	2	-	-	-	2	-	-	2
49	H.MA HIAO	990	NH		136	-	2	-	3	1	2	-	-	3
52	HOAAG HUA	626	AMR		131	-	-	-	-	1	3	-	-	1
53	PHU PA HUAK	132	LFB		26	-	-	-	-	-	3	-	-	1
56	H. KHOK	538	LFB		131	-	-	-	3	-	2	-	-	1
61	NAM MANG NGAI	944	AMR		169	-	2	-	-	-	1	-	-	1
62	HUAI THUAI	739	KP	3,289	142	-	-	-	-	3	1	-	-	2
63	HUAI HO	691	KP		136	-	1	-	-	3	1	-	-	2
65	HUAI BANG HAAK	938	KP		159	-	-	3	-	3	1	-	-	3
69	HUAI MUK	792	KP	3,410	145	-	-	-	-	3	1	-	-	3
78	HUAI BANG LIENG	695	BP	3,699	206	-	2	-	-	1	1	-	-	2
84	PREK MUN	476	KP		121	-	-	-	-	3	2	-	-	2

6.2 Wetlands

The presence of wetlands in the catchments of the tributaries is indicative of their biodiversity interest, and these have been classified into the percentage of natural wetlands and of riverine wetlands in the catchment. For some catchments it has been possible to identify the Ramsar wetlands of international importance and the presence of a number of regionally important wetlands, identified by the MRC in 2003.

6.2.1 Large tributaries

For the large tributaries the following have the largest proportion of natural and riverine wetlands in their catchments:

- Nam Songkhram (riverine)
- Nam Chi
- Se San (riverine)
- Siem Bok (natural and riverine)
- Stung Chinit (natural)
- Delta (natural and riverine)

The tributaries that contain internationally and regionally important wetlands in their catchments include:

- Nam Mae Kok, Nam Mae Ing, Nam Ngum in the Northern Highlands
- Nam Songkhram, Nam Chi and Nam Mun in the Khorat Plateau
- Nam Cadinh, Se Bang Hieng in the Annamites
- Se Kong, Se San and Sre Pok from the Central Highlands
- Stung Sen, Siem Bok, Stung Pursat and Stung Baribo of the tributaries flowing into the Tonle Sap
- Delta

Table 6-4: Significance groupings for wetlands occurring in large tributaries

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length (all stream orders)	% wetlands in catchment area		Presence of Ramsar site in catchment	Number of Regionally important wetlands
		sq km			Length	% natural wetlands	% riverine		
				km	km				
1	NAM OU	26,033	NH	2,443	5,740	1	1		
3	NAM THA	8,918	NH	2,203	1,029	1	1		
5	NAM MAE KOK	10,701	NH	2,115	1,833				2
6	NAM SUONG	6,578	NH	2,453	1,070	1	1		
15	NAM KHAN	7,490	NH	2,467	1,454	1	1		
16	NAM MAE ING	7,267	NH	2,176	1,682				4
24	NAM NGUM	16,906	NH	3,039	3,365	1	1		1
29	NAM CADINH	14,822	AMR	3,173	2,981	1	1		1
42	NAM SONGKHRAM	13,123	KP	3,265	2,759	2	3	Bung Kong Long	2
59	SE BANG FAI	10,407	AMR	3,364	1,583	2	2		
60	NAM CHI	49,133	KP	3,632	9,303	3	2		13
66	SE BANG HIENG	19,958	AMR	3,496	5,114	1	1	Xe Champhone	2
71	SE KONG	28,815	KM	3,901	4,932	1	2	Beung Kiat Nong	6
72	NAM MUN	70,574	KP	3,632	12,192	2	2		10
74	SE DONE	7,229	AMR	3,677	2,249	1	1		
77	SE SAN	18,888	KM	3,900	2,785	1	3		1
81	ST.SRENG	9,986	NTS	TS	2,091	2	1		
82	ST. SEN	16,360	NTS	TS	3,182	2	1		2
83	ST.MONGKOL BOREY	14,966	NTS	TS	3,171	2	1		
86	SRE POK	30,942	KM	3,900	6,729	1	2		1
87	SIEM BOK	8,851	NTS		2,258	3	3		4
91	ST.CHINIT	8,237	NTS	TS	1,748	3	2		
98	ST.PURSAT	5,965	CM	TS	1,597	2	1		1
101	ST.BARIBO	7,154	CM	TS	2,192	2	2		3
102	PREK CHHLONG	5,957	VU	4,077	1,713	1	2		
103	DELTA	48,235	D	4,313	5,467	3	3		16
104	PREK THNOT	6,124	CM	4,285	1,740	2	2		

6.2.2 Medium tributaries

Of the medium tributaries, the following contain important areas of wetlands:

- Nam Phuong (riverine)
- Nam Heung, Huai Nam Son and Huai Mong, Nam Loei from LFB
- Huai Bang Bot (riverine) H.Nam Huai, Nam Kam, Huai Bang Sai, Huai Bang I, Huai Bang Koi, Huai Khamuan from Khorat Plateau
- Huai Som Pak and Se Bang Nouan from the Annamites
- Huai Tomo from the Bolevan Plateau
- Stung Staung, Stung Sangker and the Tonle Sap itself
- Prek Preah (riverine)

The following contain internationally and regionally important wetland areas:

- Nam Nae Kham
- Huai Bang Bot
- Huai Mong
- Nam Suai
- Nam Kam
- Huai Tomo
- Tonle Repon
- O Talas
- Stung Chikreng, Stung Staung, and the Tonle Sap
- Stung Sangker, Stung Battambang and Stung Dauntri from the Cardamon mountains

Table 6-5: Significance groupings for wetlands in medium tributaries

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length (all stream orders)	% wetlands in catchment area		Presence of Ramsar site in catchment	Number of Regionally important wetlands
		sq km			Length	% natural wetlands	% riverine		
				km	km				
2	NAM NUAO	2,287	NH	1,966	259	1	2		
4	NAM MA	1,141	NH	1,998	110	1	1		
7	NAM PHO	2,855	NH	2,005	395	1	1		
8	NAM MAE KHAM	4,079	NH	2,112	1,046			Nong Bong Kai	1
11	NAM NGAOU	1,495	NH	2,154	193	1	1		
12	NAM BENG	2,131	NH	2,307	176	1	1		
18	NAM KHOP	1,521	NH		345	1	2		
19	NAM TAM	1,548	NH		217	1	2		
20	NAM NAGO	1,008	NH		220	1	2		
21	NAM SING	2,681	NH		438	1	2		
22	NAM PHUONG	4,139	NH		417	1	3		
23	NAM NGEUN	1,819	NH	2,322	323	1	0		
25	NAM HOUNG	2,872	NH		556	1	1		
26	NAM NHIEP	4,577	NH	3,123	707	1	1		
27	NAM PHOUL	2,095	NH	2,581	348	1	1		
28	NAM SANE	2,226	NH	3,130	443	1	1		
31	NAM NHIAM	1,990	NH	2,686	265	1	1		
32	NAM MANG	1,836	NH	3,080	425	1	1		
35	NAM SANG	1,290	NH	2,881	109	1	2		
38	H.BANG BOT	2,402	KP	3,071	462	2	3	Kut Ting	1
39	NAM MI	1,032	NH		83	1	1		
47	NAM HINBOUN	2,529	AMR	3,282	421	1	1		
48	H.NAM HUAI	1,755	KP		244	3	1		
50	NAM HEUNG	4,901	LFB	2,778	1,106	3	1		
51	HUAI NAM SOM	1,072	LFB	2,903	152	3	1		
54	HUAI LUANG	4,090	LFB	3,023	830	2	1		
55	HUAI MONG	2,700	LFB	2,952	545	3	1		1
57	NAM SUAI	1,247	LFB	3,014	277	2	1		1
58	NAM LOEI	4,012	LFB	2,789	639	3	1		
64	NAM KAM	3,495	KP	3,366	754	3	2		1
67	HUAI SOM PAK	2,516	AMR		584	2	3		
68	HUAI BANG SAI	1,367	KP	3,401	255	3	2		
70	HUAI BANG I	1,496	KP	3,439	243	3	2		
73	H.BANG KOI	3,313	KP		658	3	2		
75	SE BANG NOUAN	3,048	AMR	3,517	870	2	3		
76	HUAI KHAMOUAN	3,762	KP	3,750	618	2	3		
79	HUAI TOMO	2,611	BP	3,719	615	2	3		1
80	TONLE REPON	2,379	KP	3,813	309	2	1		1
85	O TALAS	1,448	NTS	3,864	254	1	1	Stung Treng	1
88	ST.CHIKRENG	2,714	NTS	TS	778	2	1	Boeng Chhmar	1
89	ST.SIEM REAP	3,619	NTS	TS	892	2	1		
90	ST.STAUNG	4,357	NTS	TS	1,070	3	1	Boeng Chhmar	1
92	PREK PREAH	2,400	KM	3,964	463	2	3		
93	ST.SANGKER	2,344	CM	TS	530	3	1		1
94	ST.BATTAMBANG	3,708	CM	TS	1,207	2	1		1
95	TONLE SAP	2,744	TS	4,263	325	3	3	Boeng Chhmar	1
96	PREK KRIENG	3,332	KM	3,968	911	1	2		
97	ST.DAUNTRI	3,696	CM	TS	891	2	1		1
99	PREK KAMP	1,142	KM	4,020	309	1	2		
100	PREK TE	4,364	VU	4,040	1,189	1	2		

6.2.3 Small tributaries

The small tributaries that have significant percentages of wetlands include

- Nam Ngam, Huay Sophay, Phu Luong Yot Huai Dua, Nam Kai and Huay Ma Haio from the Northern Highlands
- Hoag Hua and Nam Mang Ngai from the Annamites
- Phu Pa Huak and Huai Khok from the LFB,
- Huai Thuai, Huai Ho, Huai Bang Haak and Huai Muk and Prek Mun from the Khorat Plateau

The only two small tributaries that contain regionally important wetland areas are the Huai Ma Hiao and the Huai Bang Lieng.

Table 6-6: Significance groupings for wetlands in small tributaries

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length (all stream orders)	% wetlands in catchment area		Presence of Ramsar site in catchment	Number of Regionally important wetlands
		sq km			Length	% natural wetlands	% riverine		
				km	km				
9	B.KHAI SAN	778	NH		73	1	2		
10	NAM KEUNG	633	NH	2,099	52	1	2		
13	DOI LUANG PAE MUANG	688	NH	2,116	125				
14	NAM NGAM	489	NH	2,142	68	2	3		
17	NAM MAE NGAO	485	NH	2,188	69	1	1		
30	NAM NHAH	316	NH		63	1	1		
33	MUANG LIEP	488	NH		66	1	2		
34	NAM TON	587	NH	2,903	107	1	1		
36	NAM THONG	455	NH		129	1	2		
37	NAM KADUN	456	AMR		83	2	2		
40	NAM PHONE	664	NH		101				
41	B.NAM SONG	138	NH		4	1	2		
43	H.SOPHAY	186	NH		85	2	3		
44	NAM THON	838	AMR	3,205	243	1	2		
45	PHU LUONG YOT HUAI DUA	491	NH		54	1	3		
46	NAM KAI	602	NH		71	1	2		
49	H.MA HIAO	990	NH		136	2	3		1
52	HOAAG HUA	626	AMR		131	2	3		
53	PHU PA HUAK	132	LFB		26	3	3		
56	H. KHOK	538	LFB		131	2	3		
61	NAM MANG NGAI	944	AMR		169	2	3		
62	HUAI THUAI	739	KP	3,289	142	3	2		
63	HUAI HO	691	KP		136	3	2		
65	HUAI BANG HAAK	938	KP		159	3	3		
69	HUAI MUK	792	KP	3,410	145	3	2		
78	HUAI BANG LIENG	695	BP	3,699	206	1	2		1
84	PREK MUN	476	KP		121	3	3		

6.3 Ecosystem connectivity

An elegant example for a simple network connectivity index has been developed by Cote et al. (2009): The Dentritic Connectivity Index (DCI) uses network analysis to evaluate the cumulative impact of the number, permeability, and location of barriers on the life history of potamodromous and diadromous fish. This does not include a classification of river ecosystems of habitats.

Lehner et al (2011) have developed a new River Ecosystem Connectivity Index (RECI) from the concepts developed for the Mekong by Sindorf and Wickel (2011) taking into account the following parameters that define river habitats. [5]

- **Discharge.** River size is frequently used in habitat classifications, sometimes substituted by river length or upstream basin area if discharge information is unavailable. We used long-term average discharge as a first-order proxy for hydrology and river reach morphology by categorizing three stream orders: small streams (<100 m3/s), medium tributaries (100-1000 m3/s), and the Mekong main stem (≥1000 m3/s).
- **Floodplains**. Floodplain systems represent highly distinct aquatic ecosystem types in the MRB due to their complex hydrological and ecological dynamics (e.g., channel morphology, lateral migration of biota, sedimentation). We derived an associated floodplain coverage for each river reach based on the maximum flooding extent as delineated on a global map by Fluet-Chouinard and Lehner (in prep.). The presence of more than 50% of floodplain area within a 5km buffer around each river reach was used to distinguish major floodplain influence.
- **Karst.** Karstic environments have been acknowledged as another indicator of highly unique aquatic ecosystem types in the MRB. These environments are considered hotspots for endemism because of their capacity to easily create cave systems, i.e. environments prone to specialization of species (Kottelat and Whitten 1996; Williams 2008). Following the approach by Sindorf and Wickel (2011), we used carbonate outcrops as a proxy for karstic environments based on a global map by Williams and Ford (2006). We classified reaches as ‘karst’ types if more than 75% of their respective upstream watershed area is covered by karst.
- **Ecological regions/Elevation**. Elevation is frequently used as a major descriptor of largely different aquatic subregions such as the Himalayan headwaters and the middle and lower parts of the MRB. Here, we decided to use ‘ecological regions’ as a superior indicator that combines topography with available information on the general ecology of the MRB. Following other authors, we defined ecological regions as units where the biota have to adapt to similar constraints and resources, which can result from climate, river regime, and geomorphology among other factors. We use breaks, or thresholds, located along the main stem of the Mekong to distinguish six different ecological regions:
    - **Himalayas**. The first ecological region is comprised of the headwater streams in the Himalayan Mountains, many of which are steep and glacier fed. The region’s lower boundary around the border of China represents an important break in the basin physiology, where the landscape tilts from a ‘mountainous’ one to a ‘plains and

[5] This section is abstracted from the paper by Lehner et al. which provides full details of methods and explanations.

plateau' type. This breakpoint coincides with an elevation threshold of approximately 850m (Kang et al. 2009).

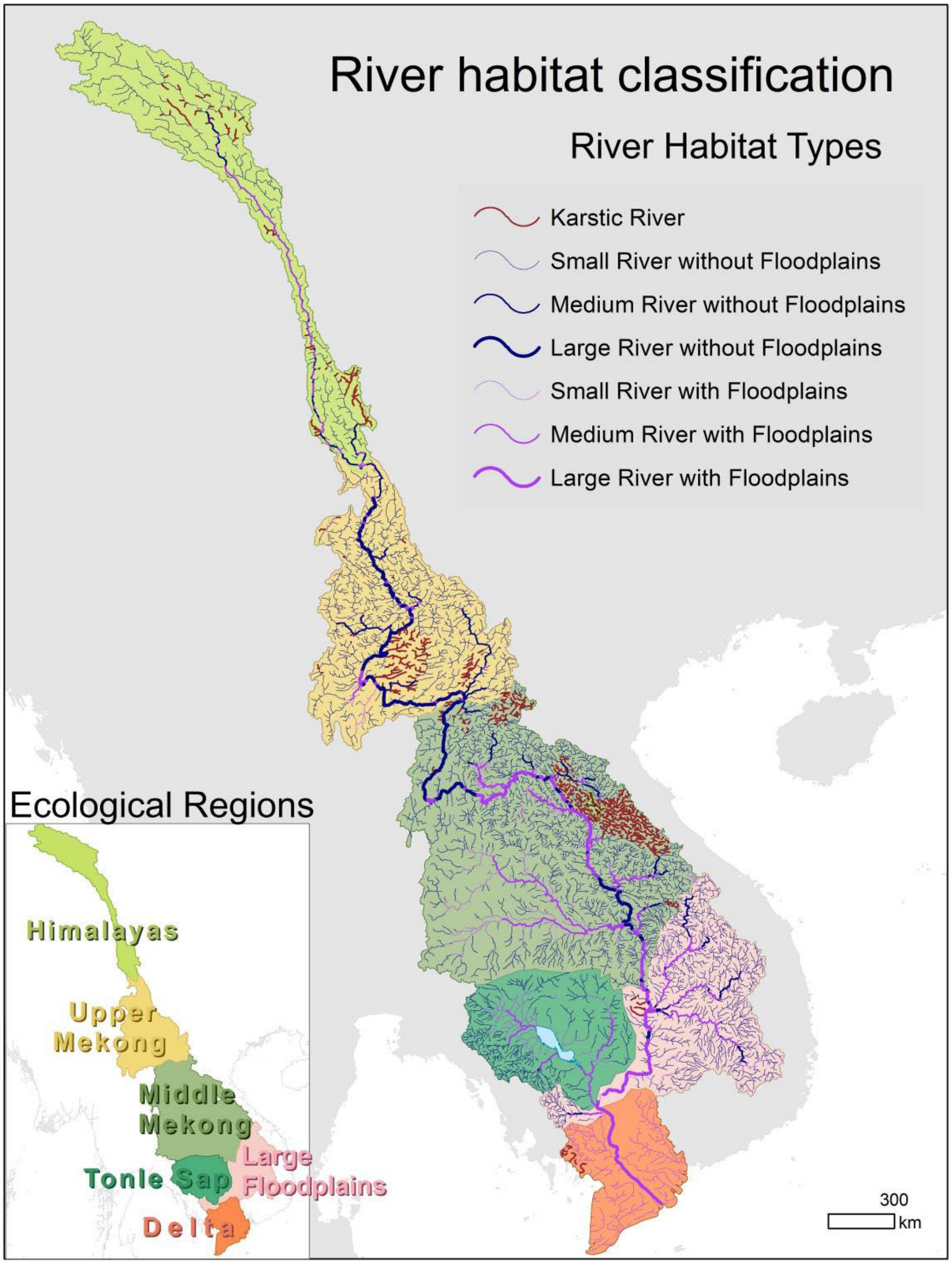
- **Upper Mekong**. The Upper Mekong region ends at the city of Luang Prabang and is characterized by narrow gorges and incised meanders (Kang et al. 2009; Baran 2010; Gupta and Liew 2007). It is a transition zone between the cold and fast flowing waters of the Himalaya region and the warmer and slower waters of the lower regions (Kang et al. 2009). This region also represents the limit of the upper migration zone as defined by Poulsen et al. (2002).
- **Middle Mekong.** The Middle Mekong has its lower boundary at Khone Falls and includes the Khorat Plateau. This region is not as well defined in the literature as the two previous ones; e.g. Kang et al. (2009) merged it with the Upper Mekong, while Abell et al. (2008) defined a specific ecoregion for the Khorat Plateau moving the boundary down to the city of Kratie. The Middle Mekong as defined here represents an area where the landscape is dominated by plains. Khone Falls act as an important barrier at the lower system boundary. According to Baran (2010), the percentage of endemic species increases significantly (from 14% to 29%) upstream of this natural barrier. This area covers most of the middle migration zone as defined by Poulsen et al. (2002).
- **Floodplains.** The fourth ecological region is located between Khone Falls and Phnom Penh and is mainly characterized by extensive continuous floodplains (Kang et al. 2009; Baird and Flaherty 2005). The Mekong main stem in this region is an anastomosed channel with a multitude of bars and islands (Baird and Flaherty 2005; Gupta and Liew 2007). It covers part of the lower migration zone as defined by Poulsen et al. (2002).
- **Tonle Sap.** The fifth ecological region represents the subbasin of the Tonle Sap Lake down to the confluence of its outflow with the Mekong River. The Tonle Sap is a shallow lake that is characterized by enormous annual flooding caused by Mekong flows that are pushed upstream during the wet season (Campbell et al. 2006).
- **Delta.** The last ecological region represents the Mekong Delta with its upstream boundary located at Phnom Penh (Baird and Flaherty 2005; Campbell et al. 2006; Kang et al. 2009; Baran 2010). As one of the world's largest deltas, it is characterized by tidal influences as well as the intrusion of saline water (Baran 2010).

- **Special features**. In addition to the applied classification criteria as outlined above, we considered to include waterfalls (as natural breaks in the river system); deep pools (as unique habitat types); major migration zones; and the occurrence of highly threatened species as special features in the classification to derive a more complete aquatic ecosystem classification. However, we abstained from their final inclusion due to lack of consistent basin-wide data (for a draft map see Figure A4 in appendix).

Figure 6-2 shows the result of the river habitat classification. By combining 7 basic river types with 6 ecological regions (see legend of figure 2) we derived a total of 27 individual classes (note that from the theoretical 42 combinations several do not occur in reality, e.g. there is no main stem class in the

Himalayan region). The majority of karstic rivers are small streams, thus we refrained from distinguishing size classes for this river type.

Figure 6-2: River habitat classification of the Mekong River Basin.

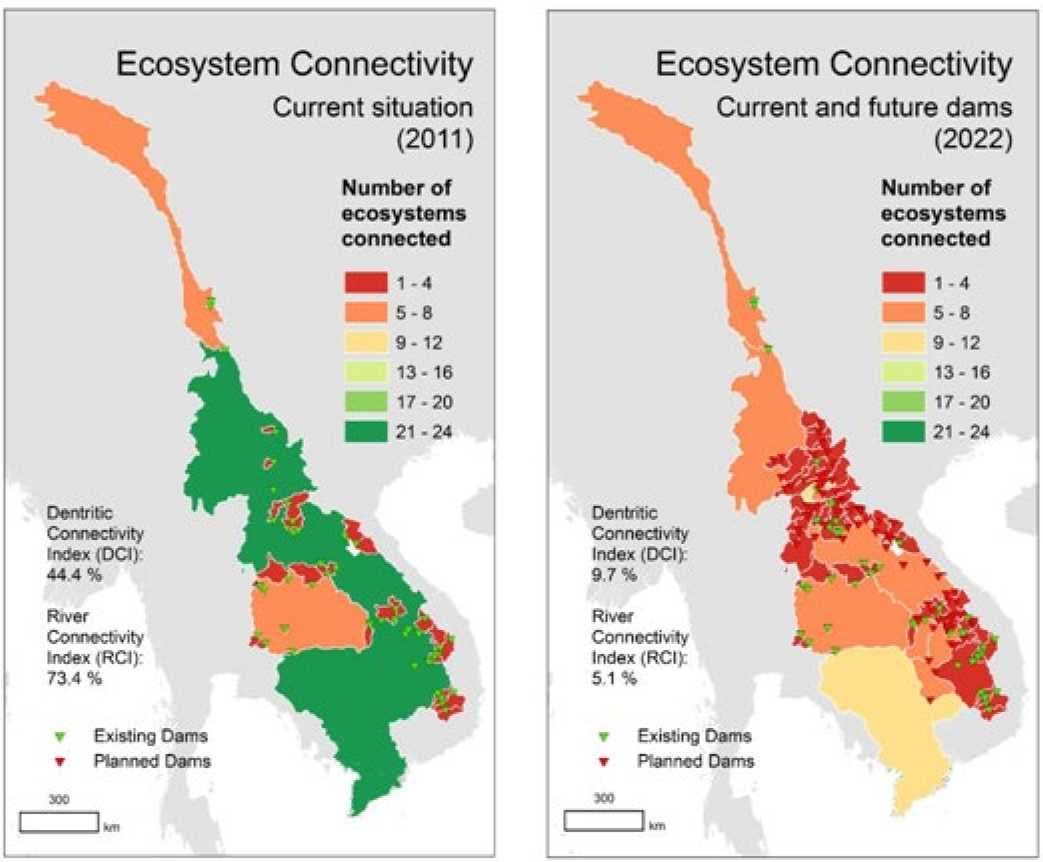


(Note: To derive the full number of classes, river habitat types need to be combined with ecological regions; e.g. there are 'Medium rivers without floodplain in the Upper Mekong' and 'Medium rivers without floodplain in the Middle Mekong', etc.)

Figure 6-3 shows ecosystem connectivity, i.e. the number of ecosystems connected per river section, as well as the overall DCI and RECI values for the MRB. The left panel portrays the current ecosystem connectivity, while the right panel depicts the scenario if all 84 planned dams were built in the year 2022. Currently almost 65% of the area of the MRB is connected in the largest contiguous section that is still unimpeded by dams, and 24 out of 27 river habitat classes are found within this section. This translates to a relatively high RECI of 73.4%. The DCI value, which does not account for the distribution of ecosystems but only considers the lengths of disconnected river sections, is currently lower at 44.4%.

In the future scenario (right panel), the largest section that remains connected accounts for only 20% of the total basin area, mostly due to dam developments on the main stem of the Mekong. The number of connected river habitat types in this largest section is reduced to 12. In this scenario, the RECI falls to 5.1%, while the DCI decreases to a slightly higher 9.7%. Further noticeable is the general fragmentation of the entire basin into much smaller sections due to the large number of newly constructed dams.

Figure 6-3: Overview of ecosystem connectivity in the Mekong River Basin for today (2011) and the future (2022).



(Note: Colored regions show the number of different habitat classes found in the remaining connected river network sections. Dendritic and River Ecosystem Connectivity Indices are calculated for reference. Both indices as well as the number of connected ecosystem are strongly reduced for the future development scenario compared to the current situation.)

7 Assessing the biodiversity indicators of significance

The assessment of the biodiversity of the tributaries is limited by the fact that there has not been a comprehensive survey of any of the aquatic biological taxa in the tributaries. The principal focus for biodiversity surveys has naturally been upon fish, and we have species lists collected for a total of 22 tributaries of Mekong (about 21%) with a reasonable spread from different parts of the basin[6]. These species lists have been consolidated from all of the known surveys carried out and represent the recorded presence of a species in a tributary at one time or another. The lists are limited by the fact that methods of survey have different sampling biases, and are therefore not directly comparable. For some tributaries there have been several surveys, for others just one, and therefore these tributaries may be under-represented.

The second method of assessing biodiversity has been the compilation of endangered species from different aquatic taxa (Critically Endangered, Endangered and Vulnerable) and the use of the IUCN Redlist to identify ranges or presence in named tributaries. The taxa considered include aquatic plants, fish, molluscs, dragonflies, amphibians. This has enabled the identification of tributaries that contain known endangered species. However, the presence of a species in one tributary should not preclude its presence or absence in another tributary where appropriate surveys have not been carried out.

The third method for assessing biodiversity is the definition of an index of biodiversity interest based upon the percentages of the catchment area lying within a recognized Protected Area and a Key Biodiversity Area. Although these are generally designated because of terrestrial biodiversity, the assumption is made that level of aquatic biodiversity interest will be similar.

7.1 Biodiversity of fish species

The estimate for biodiversity of the fish species in the tributaries of the Mekong has been developed from Multivariate analysis comparing the fish species lists from the 22 tributaries with a total of 31 independent (explanatory) variables described in this paper, including the physical, geological, ecological character of the tributaries and their degree of modification. The fish community variables of interest in each tributary, hereafter also referred to as dependent variables, were the reported number of:

- all species;
- blackfish species; Guild Number 6.
- migratory species: Migratory species included fish guild numbers 2, 3, 4, 8, and 9.
- endemic species;
- endangered species. Endangered species included the following three IUCN categories: (i) Critically Endangered; (ii) Endangered; and (iii) Vulnerable.

[6] Based upon consolidation of species lists carried out by Eric Baran, and from the publication: Halls, A.S., Conlan, I., Wisesjindawat, W., Phouthavongs, K., Viravong, S., Chan, S. and V.A.Vu (2010) An atlas of deep pools in the Lower Mekong River and some of its tributaries. MRC Technical Paper No. 32. Mekong River Commission, Vientiane. 88pp. ISSN: 1683-1489.

Community variables (ii) – (v) were also expressed as a percentage of (i). Fish communities in each of the 22 tributaries were described using a species-tributary abundance matrix. Abundance was measured in terms of presence (1) and absence (0).

After testing the fit of the different independent variables, and applying the most relevant a Multiple Linear Regression Model was applied to all the 104 tributaries to give predictions of the most likely levels of each of the dependent descriptors of the fish populations. A full description of this method and results is found in the paper, prepared for this study by Ashley Halls, entitled "Mekong River Tributaries: Assessment of Fish Communities" January 2012.

The results of this prediction of fish communities have been presented as tables below arranged by size of catchment. Where appropriate the actual estimates of the fish communities from the species lists has been included rather than the modeled figures, and the significance of the tributaries assessed by taking the 80^{th}, 50^{th}, and 20^{th} percentiles coloured in different shades of blue in the tables below (dark blue representing the highest percentiles).

7.1.1 General results of fish communities in the tributaries

The following general statements can be made from these modeled results:

- The number of species (species count) varied by almost a factor of eight among the Mekong tributaries included in the assessment. Between 40 – 50 % of the variation could be explained by single explanatory variables describing habitat density (stream density), extent/area (catchment area) and diversity (the ecological diversity index developed for the assessment). Relationships between fish species diversity and habitat area, diversity and stream order have long been reported in the literature (Welcomme, 1985).
- Contrary to the hypothesised relationships, species count declined with increasing stream density and protected area. There appear to be no obvious explanations why species count might decline with these two variables. Most (88%) of the observed variation in species count could be explained using a combination of explanatory variables describing habitat density (stream density), extent (wetlands area) and diversity (biodiversity area; ecological diversity index).
- Given that blackfish species form a relatively stable proportion of fish communities (range: 4 – 11 %; mean = 7 %, S.D. =2 %) in the tributaries included in the assessment, it was unsurprising that the number of blackfish (blackfish count) also varied in response to the same types of variables as total species count: habitat extent (catchment area; wetlands area); habitat density (stream density). Contrary to the hypothesised relationships, blackfish species count also declined with increasing stream density and protected area. However, the best multiple linear regression model contained only catchment area and wetlands area as explanatory variables. As might be expected from swamp and floodplain dwelling blackfish, their contribution to the fish community declined with the slope of second order streams (slope S.O 2) and increased with stream density. There was also evidence that the blackfish proportion increases downstream as might be expected given that longitudinal distribution of floodplain habitat in the LMB. The blackfish proportion was also found to increase with temperature possibly

reflecting blackfish physiological adaptations to extreme environmental conditions and low dissolved oxygen concentrations although this might simply be a statistical artefact given that temperature and stream slope are (negatively) correlated. Typically, the explanatory power of models for the blackfish proportion was relatively low in terms of R2 values and model fits were often poor judged from the residual plots.

- Reliable and well-fitting models for the count and proportion of migratory species were also difficult to achieve. Again, the overall number of migratory species responded to the same variables types as the total species count and blackfish count including catchment area and stream density. The best fitting MLR model explaining 87 % of the variation in migratory species count and included catchment area, average stream order and the ecological diversity index as explanatory variables. However, the best MLR for migratory species proportion accounted for only 56 % of the variation. There was some evidence to indicate that the proportion of migratory species in the community increases downstream.
- Better performing models were developed for endemic species count and endemic species proportion. Endemic species count was dependent upon habitat diversity (ecological diversity index); habitat density (stream density) and tributary confluence distance from the sea (delta). The proportion of endemic species was better explained by distance from the sea (delta) and tributary elevation. This would be expected on the grounds that endemic species are likely to evolve in more isolated (upstream areas) areas that are also less accessible to diadromous fish species.
- Endangered species count models also included variables describing habitat extent size and diversity variables (catchment area, ecological diversity index, stream density and wetlands area). Efforts to model the proportion of the fish community ‘endangered’ were unsuccessful. This is perhaps not surprising given that few tributaries are likely to contain species unique to them and that the endangered status applies across the basin irrespective of the relative abundance of the species among tributaries.
- The best fitting models appear, in most cases, to adequately predict both low and high fish community variable values for the sampled tributaries. However, given the errors associated with most of the models, confidence intervals around predicted values are likely to be wide and the accuracies of the models are unknown. The model predictions should therefore be interpreted and applied with great caution.
- The guild composition of fish communities in Cambodia and Lao PDR were found to be significantly different. Compared to Lao PDR, fish communities in Cambodian tributaries comprise fewer rithron-resident species and marginally fewer main channel spawners (guild 3); but contain, on average, more species belonging to guild 4 (migratory main channel refuge seeker); and more generalist, estuarine and blackfish species (guilds 5, 7 and 6). This pattern is consistent with the habitat distribution in the LMB. In addition to important habitat variables (geological zone; catchment area; distance from the delta; limestone area and average rainfall), the pattern of variation in guild composition among tributaries was also found to be significantly correlated with human population density and the extent of hydropower development. However, the significance of hydropower development is questioned given that the index

appears to include existing and potential hydropower development. It is unclear how and why population density might affect guild composition.

7.1.2 Large tributaries

When the fish communities of the large tributaries are considered the following points can be made:

- **Species counts** – The Delta stands out as having by far the highest numbers of species, largely because it contains both marine and estuarine species. It is followed by the Nam Mun and Nam Chi and Nam Songkhram on the Khorat Plateau, two of the 3S rivers – the Se Kong and Sre Pok, the Stung Mongkol Borey of the tributaries flowing into the Tonle Sap, The Se Bang Hieng and Se Bang Fai originating in the Annamites and the Nam Mae Kok in the Northern Highlands.

- **Blackfish species -** The highest number of blackfish species were recorded in the Delta and the Nam Songkhram, followed by the Nam Chi and Nam Mun, the Sre Pok and several of the tributaries flowing into the Tonle Sap (St. Sen, Mongkol Borey, Chinit, Pursat) and also Siem Bok and the Se Bang Hieng. All of these have significant areas of floodplains associated with them.
- The lowest numbers of blackfish species were found in the Nam Ou.
- In terms of the proportion of blackfish species, the Nam Songkhram, Stung Chinit and Stung Baribo are the highest, followed by the Nam Cadinh, Stung Sen and Siem Bok, Prek Chhlong and Prek Thnot. The lowest proportions are found in the north, the Nam Ou, Nam Suong and Nam Khan, but also in the Se Kong and interestingly in the Delta (where the total numbers of species are higher because of the presence of marine and estuarine fish)**.**

- **Migratory fish species -** the highest numbers of migratory fish species are found in many of these rivers throughout the system representing both migratory origins and destinations, with a strong linkage with the length of the tributary, e.g. Nam Ou, Nam Mae Kok and Nam Ngum from the Northern Highlands, Nam Mun, Nam Chi and Nam Songkhram in the Khorat Plateau, Sre Pok and Se Kong from the Central Highlands, Se Bang Hieng and Se Bang Fai from the Annamites, Stung Mongkol Borey, Stung Pursat and Stung Baribo, Prek Chhlong and Prek Thnot and the Delta.
- The tributaries with the least migratory fish include the Nam Suong and the Nam Cadinh.
- In terms of proportion of migratory fish, the most significant tributaries are the Se Done and Se San, Stung Sen and Siem Bok, Stung Pursat, Stung Baribo, Prek Chhlong and Prek Thnot. Those with the lowest proportionof migratory fish are the Nam Cadinh and the Delta.

- **Endemic fish species –** the tributaries with the highest number of endemic species are mostly those furthest from the sea, including Nam Tha, Nam Mae Kok, Nam Khan. The Nam Chi and Nam Mun, the Se Bang Hieng and Se Bang Fai, the Se Kong and the Sre Pok. The tributaries with the highest proportions of endemic species are the Nam Tha, Nam Mae Kok, Nam Mae Ing, Nam Cadinh.

- **Endangered species –** The tributaries with the highest numbers of endangered species include the Nam Mun and Nam Chi, the Delta, the Se Kong , Se San and Sre Pok, and Se Done; Stung Mongkol Borey, Stung Pursat and Stung Baribo and Prek Thnot from the Cardamon mountains.

Table 7-1: Results and significance groupings for predicted fish species in large tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	Species count	Blackfish species	Blackfish species %	Migratory species	Migratory species %	Endemic species	Endemic species %	Endangered species
			sq km	km		MLRM	MLRM	MLRM	MLRM	MLRM	MLRM	SLRM	MLRM
1	NAM OU	3	26,033	5,740	NH	136	6	4	51	38	37	27	13
3	NAM THA	3	8,918	1,029	NH	149	7	5	33	34	48	38	6
5	NAM MAE KOK	3	10,701	1,833	NH	208	7	5	62	38	58	40	12
6	NAM SUONG	3	6,578	1,070	NH	118	7	3	28	38	39	35	5
15	NAM KHAN	3	7,490	1,454	NH	125	7	0	45	40	42	35	8
16	NAM MAE ING	3	7,267	1,682	NH	99	7	8	50	43	39	39	7
24	NAM NGUM	3	16,906	3,365	NH	154	7	5	52	34	41	27	11
29	NAM CADINH	3	14,822	2,981	AMR	95	9	9	27	28	36	38	4
42	NAM SONGKHRAM	3	13,123	2,759	KP	220	22	10	88	40	39	18	20
59	SE BANG FAI	3	10,407	1,583	AMR	157	8	5	58	37	52	33	8
60	NAM CHI	3	49,133	9,303	KP	265	19	7	113	43	47	18	26
66	SE BANG HIENG	3	19,958	5,114	AMR	158	11	7	62	39	47	30	9
71	SE KONG	3	28,815	4,932	KM	213	9	4	79	37	62	29	21
72	NAM MUN	3	70,574	12,192	KP	265	19	7	113	43	47	18	26
74	SE DONE	3	7,229	2,249	AMR	100	7	8	50	49	25	21	13
77	SE SAN	3	18,888	2,785	KM	131	7	5	57	44	23	18	15
81	ST.SRENG	3	9,986	2,091	NTS	112	8	8	48	41	17	14	9
82	ST. SEN	3	16,360	3,182	NTS	116	11	9	51	44	14	12	10
83	ST.MONGKOL BOREY	3	14,966	3,171	NTS	171	10	7	65	42	28	14	15
86	SRE POK	3	30,942	6,729	KM	237	13	5	93	39	43	18	18
87	SIEM BOK	3	8,851	2,258	NTS	122	10	9	41	45			15
91	ST.CHINIT	3	8,237	1,748	NTS	89	10	11	35	39	11	12	9
98	ST.PURSAT	3	5,965	1,597	CM	133	11	8	59	44	18	14	17
101	ST.BARIBO	3	7,154	2,192	CM	154	8	10	72	49	29	14	18
102	PREK CHHLONG	3	5,957	1,713	VU	63	7	9	41	48	15	16	9
103	DELTA	3	48,235	5,467	D	453	20	4	97	21	27	6	22
104	PREK THNOT	3	6,124	1,740	CM	141	8	9	65	47	26	13	15

7.1.3 Medium tributaries

For the medium tributaries, the following stand out:

- **Species counts –** Nam Sang and Nam Mi from Northern Highlands, H.Nam Huai and H. Bang Koi from Khorat Plateau, with the largest number being recorded in the Tonle Sap. The Northern Highland tributaries have consistently middle range numbers of species, whilst the tributaries around the Tonle Sap generally have lowest numbers.

- **Blackfish species –** the medium tributaries with the highest number of blackfish species are the Nam Heung, Huai Nam Som, Nam Loei, from the LFB; H. Nam Huai, Nam Kam, H. Bang Sai, H. Bang I and H. Bang Koi from the Khorat Plateau; the Stung Sangker, Stung Dauntri from the Cardamon mountains and the Tonle Sap itself.
- Those with the lowest numbers of blackfish include the Nam Mang, Stung Chikreng, Stung Siem Reap and Stung Staung.
- In terms of highest proportions of blackfish, the most significant tributaries are the Nam Mae Kham and Nam Phuong, in the Northern highlands, Huai Som Pak from the Annamites, Huai Tomo from the Bolevan, the Stung Battambang and Stung Dauntri and three of the 4P rivers – Prek Kreing, Prek Kamp and Prek Te. The lowest proportions of black fish tend to be found in the tributaries in the Northern Highlands.

- **Migratory fish species –** The highest numbers of migratory fish are found in the Nam Mae Kham, the H. Bang Koi, Stung Sangker, and the Tonle Sap which has the highest number. In terms of highest proportions of migratory fish, the Nam Mae Kham, Se Bang Nouan, St Chikreng, Stung Siem Reap, Stung Staung, Stung Sangker, Stung Battambang, Stung Dauntri, and Prek Krieng, Prek Kamp and Prek Te stand out.
- The tributaries with the lowest proportion of migratory fish are the Nam Ma, Nam Beng, Nam Phuong, Nam Nhiep, Nam Sane, Nam Mang, and Nam Sang all from the Northern Highlands, the H. Bang Bot from the Khorat Plateau, Nam Hinboun from the Annamites and the O Talas.

- **Endemic fish species –** The tributaries with the highest numbers and proportions of endemic species are all from the Northern Highlands – Nam Nuao, Nam Ma, Nam Pho, Nam Mae Kham, Nam Ngaou, Nam Beng and Nam Ngeun.
- Those tributaries with the lowest numbers of endemic species include Huai Tomo from the Bolevan, O Talas, Stung Chikreng, Stung Siem Reap, Stung Staung, Stung Battambang, Stung Dauntri, and Prek Krieng, Prek Kamp and Prek Te.

- **Endangered species –** The tributaries with the highest numbers of endangered species are the H. Nam Huai and Nam Heung and Huai Bang Sai and Huai Bang Koi from LFB and Khorat Plateau. The Stung Sangker, and Stung Dauntri, and the Tonle Sap.
- Those with the lowest number of endangered species are Nam Nuao, Nam Beng, Nam Nhiam, Nam Mang, Nam Mi, from the Northern Highlands and the Tonle Repon and O Talas.

Table 7-2: Results and significance groupings for predicted fish species in medium tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	Species count	Blackfish species	Blackfish species %	Migratory species	Migratory species %	Endemic species	Endemic species %	Endangered species
			sq km	km		MLRM	MLRM	MLRM	MLRM	MLRM	MLRM	SLRM	MLRM
2	NAM NUAO	2	2,287	259	NH	126	6	0	7	34	43	41	2
4	NAM MA	2	1,141	110	NH	131	6	6	9	32	48	41	3
7	NAM PHO	2	2,855	395	NH	122	6	6	21	36	46	41	4
8	NAM MAE KHAM	2	4,079	1,046	NH	127	6	9	64	45	48	40	11
11	NAM NGAOU	2	1,495	193	NH	134	6	6	11	35	43	39	3
12	NAM BENG	2	2,131	176	NH	147	6	1	5	31	42	37	1
18	NAM KHOP	2	1,521	345	NH	82	6	5	19	43			4
19	NAM TAM	2	1,548	217	NH	129	6	3	11	36			4
20	NAM NAGO	2	1,008	220	NH	84	6	1	13	42			4
21	NAM SING	2	2,681	438	NH	119	6	4	15	38			4
22	NAM PHUONG	2	4,139	417	NH	199	7	10	20	33			6
23	NAM NGEUN	2	1,819	323	NH	124	6	6	26	39	41	37	5
25	NAM HOUNG	2	2,872	556	NH	109	6	0	35	40			5
26	NAM NHIEP	2	4,577	707	NH	150	6	4	35	27	36	27	6
27	NAM PHOUL	2	2,095	348	NH	136	6	3	29	38	40	34	6
28	NAM SANE	2	2,226	443	NH	113	6	4	32	29	30	27	6
31	NAM NHIAM	2	1,990	265	NH	119	6	5	23	35	34	33	2
32	NAM MANG	2	1,836	425	NH	58	4	7	17	29	16	28	1
35	NAM SANG	2	1,290	109	NH	180	6	3	11	32	41	30	4
38	H.BANG BOT	2	2,402	462	KP	150	8	8	28	29	35	28	11
39	NAM MI	2	1,032	83	NH	158	6	5	6	31			2
47	NAM HINBOUN	2	2,529	421	AMR	81	6	7	14	28	24	25	3
48	H.NAM HUAI	2	1,755	244	KP	201	12	6	28	36	25	13	15
50	NAM HEUNG	2	4,901	1,106	LFB	123	10	7	37	43	33	32	13
51	HUAI NAM SOM	2	1,072	152	LFB	153	10	7	21	36	33	30	10
54	HUAI LUANG	2	4,090	830	LFB	110	8	8	43	41	28	29	8
55	HUAI MONG	2	2,700	545	LFB	135	9	8	38	41	34	29	11
57	NAM SUAI	2	1,247	277	LFB	91	8	8	33	42	24	29	7
58	NAM LOEI	2	4,012	639	LFB	166	10	7	33	37	38	31	12
64	NAM KAM	2	3,495	754	KP	119	10	8	41	42	24	24	12
67	HUAI SOM PAK	2	2,516	584	AMR	91	6	9	49	43			6
68	HUAI BANG SAI	2	1,367	255	KP	133	14	6	30	40	20	24	16
70	HUAI BANG I	2	1,496	243	KP	131	10	7	14	38	23	24	10
73	H.BANG KOI	2	3,313	658	KP	229	12	7	60	41			19
75	SE BANG NOUAN	2	3,048	870	AMR	75	7	8	33	47	22	23	10
76	HUAI KHAMOUAN	2	3,762	618	KP	138	8	7	32	38	28	20	9
79	HUAI TOMO	2	2,611	615	BP	68	8	9	18	43	13	20	7
80	TONLE REPON	2	2,379	309	KP	64	7	6	16	35	19	19	2
85	O TALAS	2	1,448	254	NTS	61	6	7	18	31	14	19	2
88	ST.CHIKRENG	2	2,714	778	NTS	68	5	7	33	49	9	13	9
89	ST.SIEM REAP	2	3,619	892	NTS	65	5	8	31	48	9	14	9
90	ST.STAUNG	2	4,357	1,070	NTS	66	5	8	32	48	9	14	9
92	PREK PREAH	2	2,400	463	KM	89	6	8	12	40	15	17	4
93	ST.SANGKER	2	2,344	530	CM	119	10	8	53	45	19	16	16
94	ST.BATTAMBANG	2	3,708	1,207	CM	62	7	10	42	51	6	14	9
95	TONLE SAP	2	2,744	325	TS	346	20	6	126	36	40	12	28
96	PREK KRIENG	2	3,332	911	KM	69	6	10	29	46	14	17	8
97	ST.DAUNTRI	2	3,696	891	CM	100	10	10	45	45	12	12	14
99	PREK KAMP	2	1,142	309	KM	49	6	10	18	46	2	17	3
100	PREK TE	2	4,364	1,189	VU	53	6	9	35	46	13	16	7
	GRAND TOTAL		624,654	120,333									

7.1.4 Small tributaries

For the small tributaries the following stand out:

- **Species counts -** the highest species counts are found in the Nam Keung, Ban Nam Song, Phu Luong Yot Huai Du, H. Ma Hiao from the Norther Highlands and the Huai Bang Haak from the Khorat Plateau.
- The lowest species counts are found in the Nam Thong, H. Sophay, Nam Thon, Hoaag Gua, from Northern Highlands and Phu Pa Huak, H. Khok from LFB, Prek Mun from the Khorat and the Huai Bang Lieng from the Bolevan Plateau.

- **Blackfish species** – None of the small tributaries stand out for black fish, although the Nam Thong, H. Sophay and Nam Thon and H. Khok have high proportions of Blackfish.

- **Migratory fish species** – The B. Khai San has the highest number of migratory fish of all the small tributaries followed by the Phu Luong Yot Huai Du and the Huai Muk. In terms of the highest proportion of migratory fish the H. Sophay, H. Khok, Huai Bang Lieng and Prek Mun stand out amongst the small tributaries.

- **Endemic fish species –** The small tributaries having the highest number of endemic species are the Nam Keung and Nam Ngam which also have the highest proportion of endemic species along with Doi Luang Pae Muang and Nam Mae Ngao. All these are from the Northern Highlands.

- **Endangered species –** The small tributaries generally have lower numbers of endangered species, although the Phu Luong Yot Huai Du, H.Ma Hiao, Huai Thuai, Huai Ho, Huai Bang Haak and Prek Mun have medium level numbers of endangered species.

Table 7-3: Results and significance groupings for predicted fish species in small tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	Species count	Blackfish species	Blackfish species %	Migratory species	Migratory species %	Endemic species	Endemic species %	Endangered species
			sq km	km		MLRM	MLRM	MLRM	MLRM	MLRM	MLRM	SLRM	MLRM
9	B.KHAI SAN	1	778	73	NH	146	6	0	65	32			2
10	NAM KEUNG	1	633	52	NH	157	6	5	6	31	46	40	2
13	DOI LUANG PAE MUANG	1	688	125	NH	84	6	7	6	39	33	39	2
14	NAM NGAM	1	489	68	NH	142	6	7	13	36	45	39	5
17	NAM MAE NGAO	1	485	69	NH	121	5	7	9	36	40	39	3
30	NAM NHAH	1	316	63	NH	74	5	8	5	41			1
33	MUANG LIEP	1	488	66	NH	118	6	6	7	36			2
34	NAM TON	1	587	107	NH	76	6		2	36	21	30	0
36	NAM THONG	1	455	129	NH	36	6	10	9	28			3
37	NAM KADUN	1	456	83	AMR	88	6	8	5	26			3
40	NAM PHONE	1	664	101	NH	99	6	7	5	37			1
41	B.NAM SONG	1	138	4	NH	181	5	4	0	27			0
43	H.SOPHAY	1	186	85	NH	18	7	13	16	51			6
44	NAM THON	1	838	243	AMR	58	6	10	27	38	14	26	5
45	PHU LUONG YOT HUAI DU	1	491	54	NH	205	6	6	33	34			7
46	NAM KAI	1	602	71	NH	129	6	6	7	34			2
49	H.MA HIAO	1	990	136	NH	178	7	7	19	34	26	13	9
52	HOAAG HUA	1	626	131	AMR	71	6	8	4	31			2
53	PHU PA HUAK	1	132	26	LFB	55	9		4	40			6
56	H. KHOK	1	538	131	LFB	59	7	9	6	44			4
61	NAM MANG NGAI	1	944	169	AMR	86	6	7	7	36			3
62	HUAI THUAI	1	739	142	KP	103	9	8	9	33	21	25	7
63	HUAI HO	1	691	136	KP	103	9	8	9	37			8
65	HUAI BANG HAAK	1	938	159	KP	161	8	5	20	38			10
69	HUAI MUK	1	792	145	KP	121	8	6	30	39	25	24	8
78	HUAI BANG LIENG	1	695	206	BP	49	6	6	12	48	4	21	4
84	PREK MUN	1	476	121	KP	49	8	5	20	44			8

7.2 Other aquatic biodiversity

In Volume 2, an analysis has been done to identify various endangered aquatic species occurring in the different tributaries. The table below shows the numbers of critically endangered, endangered and vulnerable species in the taxa of aquatic plants, fish molluscs, dragon flies and amphibians. Presence of endangered species is taken as an indicator of biodiversity wealth, and it is likely that these will not be the only rare species found there.

Note that the estimates of endangered fish species from the fish communities model are not included here.

Table 7-4: Numbers of IUCN Redlisted aquatic species in tributaries of the Mekong

Code	Catchment	Aquatic plants				Fish			Molluscs			Dragonflies			Amphibia		
		CR	VU	NT	DD	CR	EN	VU	EN	VU	DD	VU	NT	DD	VU	NT	DD
1	NAM OU					2	4	4	1					1			X
24	NAM NGUM				X	1	1	6				1		4		1	X
29	NAM CADINH					1	1	2								3	X
32	NAM MANG							1									
42	NAM SONGKHRAM			3	X	4	4	11									
58	NAM LOEI		1		X					1							X
59	SE BANG FAI							8									
60	NAM CHI					4	3	13		1	1			1			X
66	SE BANG HIENG					0	1	8								2	X
70	HUAI BANG I																X
71	SE KONG					1	8	9							4		X
72	NAM MUN	1			X	4	3	13	1								
77	SE SAN					1	5	7							4	1	
79	HUAI TOMO																X
80	TONLE REPON																X
83	ST.MONGKOL BOREY														1		
86	SRE POK				X	1	4	10							1		
94	ST.BATTAMBANG														1		
95	TONLE SAP					5	6	10									
97	ST.DAUNTRI														1	1	
98	ST.PURSAT														1	1	X
101	ST.BARIBO															1	X
102	PREK CHHLONG														1		X
103	DELTA					4	4	9									
	Unspecified Lao PDR											2		2			
	Unspecified Cambodia										1	1		1			
	Unpsecified Vietnam										1	1					
	Unspecified Thailand											1	2	1			

7.3 Protected areas and key biodiversity areas

The presence of protected areas and key biodiversity areas within the catchment of a tributary is indicative that the catchment contains some special ecological areas, although most of these are based upon terrestrial biodiversity. The biodiversity interest index has been estimated by adding the percentage of the catchment under both PAs and KBAs and then scaling the sums in three grades, with a scale of 3 being having the highest biodiversity interest.

As another measure of uniqueness, the percentage of the PAs or KBAs of the total area protected in the LMB is used to highlight those tributaries which are significant within the LMB as a whole. To put this in perspective, Protected Areas make up 12.74% of the whole LMB, and Key Biodiversity Areas make up 41% of the whole LMB.

7.4 Large tributaries

Of the large tributaries, the following have the highest biodiversity interest:

- Se Kong, Se San and Sre Pok of the tributaries coming from the Central Highlands
- Stung Sen and Stung Pursat of the tributaries flowing into the Tone Sap
- Prek Chhlong arising from the Volcanic Uplands

In terms of uniqueness within the LMB, the following catchments provide the greatest contribution to Protected Areas coverage in the LMB:

- Nam Mun and Nam Chi from the Khorat plateau
- Nam Cadinh and Se Bang Hieng from the Annamites
- Se Kong, Se San and Sre Pok from the Central Highlands
- Stung Sreng, Stung Sen and Stung Chinit of the rivers flowing into the Tonle Sap
- Prek Chhlong from the Volcanic Uplands
- Delta

The catchments contributing most to the KBAs coverage in the LMB include:

- Nam Ou and Nam Tha in the Northern Highlands
- Nam Cadinh and Se Bang Fai from the Annamites
- Nam Chi from Khorat plateau
- Se Kong, Se San and Sre Pok from the Central Highlands
- Stung Sen and Stung Pursat of the rivers flowing into the Tonle Sap, the latter flowing from the Cardamon mountains
- Prek Chhlong from the Volcanic Uplands
- Delta

Table 7-5: Significance groupings for Protected Areas and KBAs, and an index of Biodiversity Interest in large tributaries

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length (all stream orders)	Protected areas		Key Biodiversity Areas		Biodiversity interest
		sq km			Length	% in catchment	% in LMB	% in catchment	% in LMB	% PA+%KBA
				km	km					
1	NAM OU	26,033	NH	2,443	5,740	1	2	2	3	1
3	NAM THA	8,918	NH	2,203	1,029	1	2	2	3	2
5	NAM MAE KOK	10,701	NH	2,115	1,833	1	1	1	2	1
6	NAM SUONG	6,578	NH	2,453	1,070	1	1	2	2	2
15	NAM KHAN	7,490	NH	2,467	1,454	1	1	2	2	2
16	NAM MAE ING	7,267	NH	2,176	1,682	1	1	1	2	2
24	NAM NGUM	16,906	NH	3,039	3,365	1	2	1	1	1
29	NAM CADINH	14,822	AMR	3,173	2,981	2	3	3	3	2
42	NAM SONGKHRAM	13,123	KP	3,265	2,759	1	1	1	1	1
59	SE BANG FAI	10,407	AMR	3,364	1,583	1	2	2	3	2
60	NAM CHI	49,133	KP	3,632	9,303	1	3	1	3	1
66	SE BANG HIENG	19,958	AMR	3,496	5,114	2	3	1	2	2
71	SE KONG	28,815	KM	3,901	4,932	2	3	3	3	3
72	NAM MUN	70,574	KP	3,632	12,192	1	3	1	2	1
74	SE DONE	7,229	AMR	3,677	2,249	1	1	1	1	1
77	SE SAN	18,888	KM	3,900	2,785	3	3	2	3	3
81	ST.SRENG	9,986	NTS	TS	2,091	2	3	1	2	2
82	ST. SEN	16,360	NTS	TS	3,182	3	3	3	3	3
83	ST.MONGKOL BOREY	14,966	NTS	TS	3,171	2	2	1	2	2
86	SRE POK	30,942	KM	3,900	6,729	3	3	3	3	3
87	SIEM BOK	8,851	NTS		2,258	2	2	2	2	2
91	ST.CHINIT	8,237	NTS	TS	1,748	2	3	2	2	2
98	ST.PURSAT	5,965	CM	TS	1,597	3	2	2	3	3
101	ST.BARIBO	7,154	CM	TS	2,192	1	1	1	2	2
102	PREK CHHLONG	5,957	VU	4,077	1,713	3	3	3	3	3
103	DELTA	48,235	D	4,313	5,467	1	3	1	3	1
104	PREK THNOT	6,124	CM	4,285	1,740	2	2	1	2	2
							12.74		41.26	

7.4.1 Medium tributaries

Of the medium tributaries, the following have the highest biodiversity interest:

- Nam Mang of Northern Highlands
- Nam Hinboun and Se Bang Nouan from the Annamites
- Huai Tomo from the Bolevan Plateau
- Tonle Repon from the southern edge of the Khorat Plateau
- O Talas, Stung Staung and Stung Chikreng from the northern plains of Cambodia
- Stung Battambang from the Cardamon mountains
- Prek Preah, Prek Krieng, Prek Kamp and Prek Te (the 4P rivers) flowing from the foothills of the Central Highlands

It should be noted that the whole of the Tonle Sap is a Biosphere Reserve, and has some significant protected areas and Ramsar sites which may be counted under some of its tributaries. Its score under this measure of biodiversity interest appears to be very low, which is an anomaly.

None of medium catchments provide the significant coverage of protected areas in the LMB, but the following have a significant coverage of KBAs:

- Tonle Repon, Stung Staung and Prek Te

Table 7-6: Significance groupings for Protected Areas and KBAs, and an index of Biodiversity Interest in medium tributaries

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length (all stream orders)	Protected areas		Key Biodiversity Areas		Biodiversity interest
		sq km			Length	% in catchment	% in LMB	% in catchment	% in LMB	% PA+%KBA
				km	km					
2	NAM NUAO	2,287	NH	1,966	259	1	1	2	1	1
4	NAM MA	1,141	NH	1,998	110	1	1	3	2	2
7	NAM PHO	2,855	NH	2,005	395	1	1	2	2	2
8	NAM MAE KHAM	4,079	NH	2,112	1,046			2	1	1
11	NAM NGAOU	1,495	NH	2,154	193			1	1	1
12	NAM BENG	2,131	NH	2,307	176			1	1	1
18	NAM KHOP	1,521	NH		345			1	1	1
19	NAM TAM	1,548	NH		217			1	1	1
20	NAM NAGO	1,008	NH		220			1	1	1
21	NAM SING	2,681	NH		438			1	1	1
22	NAM PHUONG	4,139	NH		417			1	1	1
23	NAM NGEUN	1,819	NH	2,322	323			1	1	1
25	NAM HOUNG	2,872	NH		556					
26	NAM NHIEP	4,577	NH	3,123	707					
27	NAM PHOUL	2,095	NH	2,581	348	1	1	1	1	2
28	NAM SANE	2,226	NH	3,130	443					
31	NAM NHIAM	1,990	NH	2,686	265	2	2	1	1	2
32	NAM MANG	1,836	NH	3,080	425	2	2	3	2	3
35	NAM SANG	1,290	NH	2,881	109			1	1	1
38	H.BANG BOT	2,402	KP	3,071	462	1	1	1	1	1
39	NAM MI	1,032	NH		83			1	1	1
47	NAM HINBOUN	2,529	AMR	3,282	421	2	1	3	2	3
48	H.NAM HUAI	1,755	KP		244			2	1	2
50	NAM HEUNG	4,901	LFB	2,778	1,106	1	1	1	1	1
51	HUAI NAM SOM	1,072	LFB	2,903	152			1	1	1
54	HUAI LUANG	4,090	LFB	3,023	830					
55	HUAI MONG	2,700	LFB	2,952	545			1	1	1
57	NAM SUAI	1,247	LFB	3,014	277					
58	NAM LOEI	4,012	LFB	2,789	639	1	1	1	1	1
64	NAM KAM	3,495	KP	3,366	754	1	1			2
67	HUAI SOM PAK	2,516	AMR		584					
68	HUAI BANG SAI	1,367	KP	3,401	255	2	1			2
70	HUAI BANG I	1,496	KP	3,439	243	1	1			1
73	H.BANG KOI	3,313	KP		658	1	1	1	1	2
75	SE BANG NOUAN	3,048	AMR	3,517	870	2	1	3	2	3
76	HUAI KHAMOUAN	3,762	KP	3,750	618	1	1	2	2	2
79	HUAI TOMO	2,611	BP	3,719	615	2	2	2	2	3
80	TONLE REPON	2,379	KP	3,813	309	1	1	3	3	3
85	O TALAS	1,448	NTS	3,864	254	3	2	3	2	3
88	ST.CHIKRENG	2,714	NTS	TS	778	3	2	2	2	3
89	ST.SIEM REAP	3,619	NTS	TS	892	1	2	1	1	2
90	ST.STAUNG	4,357	NTS	TS	1,070	3	2	2	3	3
92	PREK PREAH	2,400	KM	3,964	463	3	2	2	2	3
93	ST.SANGKER	2,344	CM	TS	530	2	1	2	2	2
94	ST.BATTAMBANG	3,708	CM	TS	1,207	2	2	2	2	3
95	TONLE SAP	2,744	TS	4,263	325	1	1	2	1	1
96	PREK KRIENG	3,332	KM	3,968	911	2	2	3	2	3
97	ST.DAUNTRI	3,696	CM	TS	891	1	2	1	1	2
99	PREK KAMP	1,142	KM	4,020	309	3	1	2	1	3
100	PREK TE	4,364	VU	4,040	1,189	3	2	3	3	3
							12.74		41.26	

7.4.2 Small tributaries

Of the small tributaries, the following have the highest biodiversity interest:

- Nam Thong from the Northern Highlands
- Prek Mun from the Khorat Plateau

None of the tributaries contribute significantly to the total coverage of PAs or KBAs, although the Nam Thong and Prek Mun have a medium coverage of KBAs.

Table 7-7: Significance groupings for Protected Areas and KBAs, and an index of Biodiversity Interest in small tributaries

Code	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Total length (all stream orders)	Protected areas		Key Biodiversity Areas		Biodiversity interest
		sq km			Length	% in catchment	% in LMB	% in catchment	% in LMB	% PA+%KBA
				km	km					
9	B.KHAI SAN	778	NH		73			1	1	1
10	NAM KEUNG	633	NH	2,099	52			1	1	1
13	DOI LUANG PAE MUANG	688	NH	2,116	125			1	1	1
14	NAM NGAM	489	NH	2,142	68			1	1	1
17	NAM MAE NGAO	485	NH	2,188	69			1	1	1
30	NAM NHAH	316	NH		63					
33	MUANG LIEP	488	NH		66					
34	NAM TON	587	NH	2,903	107	2	1	1	1	2
36	NAM THONG	455	NH		129	2	1	3	2	3
37	NAM KADUN	456	AMR		83					
40	NAM PHONE	664	NH		101	2	1			2
41	B.NAM SONG	138	NH		4					
43	H.SOPHAY	186	NH		85	2	1	3	1	2
44	NAM THON	838	AMR	3,205	243	1	1			1
45	PHU LUONG YOT HUAI DUA	491	NH		54			3	1	1
46	NAM KAI	602	NH		71			1	1	1
49	H.MA HIAO	990	NH		136	1	1	3	1	1
52	HOAAG HUA	626	AMR		131					
53	PHU PA HUAK	132	LFB		26			3	1	2
56	H. KHOK	538	LFB		131			3	1	1
61	NAM MANG NGAI	944	AMR		169	1	1	3	1	2
62	HUAI THUAI	739	KP	3,289	142					
63	HUAI HO	691	KP		136					
65	HUAI BANG HAAK	938	KP		159	1	1			1
69	HUAI MUK	792	KP	3,410	145	1	1			1
78	HUAI BANG LIENG	695	BP	3,699	206	3	1	1	1	2
84	PREK MUN	476	KP		121	3	1	3	2	3

8 Productivity of the tributaries

There has been no estimate of primary productivity of the tributaries, or indeed a systematic survey of fish yields from different tributaries. The productivity of the tributaries has been estimated from potential fish yields, measured in two ways:

- From the consumption of populations living within 5 km of the entire length of the tributary
- From estimates of production of the resident fish based on average areas of each tributary in each of the ecological zones

The estimates based on consumption of populations living within 5 km of the river will tend to bias those tributaries with high density of population. Whilst this less important a bias for large and medium sized tributaries, it can clearly distort the productivity estimates for small tributaries with high populations.

It should be noted that the total estimates of fish production of these two methods are very different, but can be explained by the fact that the lower estimates based on area do not take into account the fish production due to migratory fish. Also for this purpose, the focus is a relative comparison rather than an absolute measure of fish production in each river. The scaled measures of potential yield per kilometre of length of the river is indicative of this as is the scaled percentage of total resident fish yield in the LMB.

8.1.1 Large tributaries

When considering the productivity of the large tributaries, the greatest productivity can clearly be seen lower down in the LMB. The first tributary to score highly on all three counts (productivity by consumption, by surface area and by contribution to LMB tributary productivity) is the Nam Chi and nam Mun. This is followed by the tributaries of the Tonle Sap – St. Sreng, St. Sen, St Mongkol Borey, Stung Chinit, and Stung Baribo. Siem Bok, the Delta and Prek Thnot all score highly in all three measures.

It is interesting that Nam Songkhram, Se Bang Hieng, and Sre Pok all rivers with significant floodplain areas did not score highly when the productivity is measured by surface area, but it should be remembered that this calculation only considers the resident fish productivity within the channel areas, i.e. not floodplains. The Se Kong and Se San both scored quite low from the measure of fish yield per surface area, but more highly when considering the overall contribution of fish yield of the LMB tributaries. The Nam Ou scored highly when considering yield by consumption, low by surface area, but high for its overall contribution to LMB tributary fishery. The size of the river makes a big difference to this third measure.

Other significant northern rivers are the Nam Mae Kok and Nam Mae Ing. In the Annamites the Nam Cadinh and Se Bang Fai and Se Bang Hieng have mid-level estimated fish yields.

Table 8-1: Significance groupings for fish yield estimates in large tributaries

Code	Tributary	Size category	Catchment area	Geological zone	Total length	Total yield of fish from 5 km corridor	Total yield of fish from 5 km corridor	Potential yield of resident fish/year	Potential yield of resident fish/km/year	% of total resident fish yield in LMB
			sq km		km	Tonnes/yr	scaled	Tonnes/yr	scaled	scaled
1	NAM OU	3	26,033	NH	5,740	17,150	3	414.7	1	2
3	NAM THA	3	8,918	NH	1,029	6,007	2	34.1	1	1
5	NAM MAE KOK	3	10,701	NH	1,833	22,800	3	298.8	2	2
6	NAM SUONG	3	6,578	NH	1,070	2,891	1	43.5	1	1
15	NAM KHAN	3	7,490	NH	1,454	6,150	2	115.6	1	2
16	NAM MAE ING	3	7,267	NH	1,682	28,596	3	166.5	2	2
24	NAM NGUM	3	16,906	NH	3,365	26,619	3	480.5	2	3
29	NAM CADINH	3	14,822	AMR	2,981	1,807	1	305.7	2	2
42	NAM SONGKHRAM	3	13,123	KP	2,759	55,015	3	480.5	2	3
59	SE BANG FAI	3	10,407	AMR	1,583	10,615	2	164.2	2	2
60	NAM CHI	3	49,133	KP	9,303	203,816	3	3,733.9	3	3
66	SE BANG HIENG	3	19,958	AMR	5,114	26,154	3	568.9	2	3
71	SE KONG	3	28,815	KM	4,932	10,659	2	394.5	1	2
72	NAM MUN	3	70,574	KP	12,192	302,159	3	3,653.1	3	3
74	SE DONE	3	7,229	AMR	2,248	14,161	2	139.1	1	2
77	SE SAN	3	18,888	KM	2,785	28,673	3	205.3	1	2
81	ST.SRENG	3	9,986	NTS	2,091	15,616	3	984.2	3	3
82	ST. SEN	3	16,360	NTS	3,182	19,299	3	1,632.8	3	3
83	ST.MONGKOL BOREY	3	14,966	NTS	3,171	60,737	3	1,231.2	3	3
86	SRE POK	3	30,942	KM	6,729	81,474	3	880.4	2	3
87	SIEM BOK	3	8,851	NTS	2,258	47,609	3	598.2	3	3
91	ST.CHINIT	3	8,237	NTS	1,748	26,451	3	1,186.6	3	3
98	ST.PURSAT	3	5,965	CM	1,597	13,086	2	287.7	2	2
101	ST.BARIBO	3	7,154	CM	2,192	42,284	3	1,453.3	3	3
102	PREK CHHLONG	3	5,957	VU	1,713	8,990	2	375.0	3	2
103	DELTA	3	48,235	D	5,415	768,582	3	33,350.1	3	3
104	PREK THNOT	3	6,124	CM	1,740	44,766	3	847.3	3	3
	GRAND TOTAL		624,654			**2,186,258**		**105,102.2**		

8.1.2 Medium tributaries

This pattern of higher fish yields occurring in the south is repeated for the medium tributaries. The estimates by consumption are beginning to be influenced by the high population densities in a smaller catchment, and this is taken to the extreme in the Tonle Sap, which has a very low population density, and therefore scores very low on this estimate, but extremely high on the surface area and overall contribution estimates.

Other medium sized tributaries with high consumption based yields are Huai Luang, Nam Kam, and Stung Siem Reap. Only the Stung Siem Reap matches this high score in the surface area estimates.

When considering the surface area estimates, the medium tributaries which stand out are the Se Bang Nouan from the Annamites and the Tonle Sap tributaries – St. Chikreng, St. Siem Reap, St. Staung, St. Sangker, St. Battambang, St. Dauntri.

The 4P rivers are generally of lower productivity, although Prek Te scores highly on the surface area estimates.

In the Northern Highlands, the Nam Mae Kham, Nam Houng, Nam Sane are more productive than others, but generally have lower yields than the tributaries to the south.

Table 8-2: Significance groupings for fish yield estimates in medium tributaries

Code	Tributary	Size category	Catchment area	Geological zone	Total length	Total yield of fish from 5 km corridor	Total yield of fish from 5 km corridor	Potential yield of resident fish/year	Potential yield of resident fish/km/year	% of total resident fish yield in LMB
			sq km		km	Tonnes/yr	scaled	Tonnes/yr	scaled	scaled
2	NAM NUAO	2	2,287	NH	259	1,331	1	37.4	2	1
4	NAM MA	2	1,141	NH	110	433	1	3.4	1	1
7	NAM PHO	2	2,855	NH	395	592	1	16.5	1	1
8	NAM MAE KHAM	2	4,079	NH	1,046	10,311	2	159.0	2	2
11	NAM NGAOU	2	1,495	NH	193	1,345	1	6.9	1	1
12	NAM BENG	2	2,131	NH	176	2,882	1	3.7	1	1
18	NAM KHOP	2	1,521	NH	345	807	1	23.4	1	1
19	NAM TAM	2	1,548	NH	217	605	1	12.0	1	1
20	NAM NAGO	2	1,008	NH	220	786	1	10.5	1	1
21	NAM SING	2	2,681	NH	438	726	1	24.0	1	1
22	NAM PHUONG	2	4,139	NH	417	5,520	2	10.6	1	1
23	NAM NGEUN	2	1,819	NH	323	3,468	1	20.3	1	1
25	NAM HOUNG	2	2,872	NH	556	2,221	1	47.9	2	2
26	NAM NHIEP	2	4,577	NH	707	1,290	1	46.9	1	2
27	NAM PHOUL	2	2,095	NH	348	2,916	1	25.4	1	1
28	NAM SANE	2	2,226	NH	443	813	1	63.6	2	2
31	NAM NHIAM	2	1,990	NH	265	1,175	1	25.3	2	1
32	NAM MANG	2	1,836	NH	425	1,307	1	32.2	1	1
35	NAM SANG	2	1,290	NH	109	191	1	5.8	1	1
38	H.BANG BOT	2	2,402	KP	462	12,868	2	46.6	2	2
39	NAM MI	2	1,032	NH	83	604	1	3.3	1	1
47	NAM HINBOUN	2	2,529	AMR	421	2,211	1	34.0	1	1
48	H.NAM HUAI	2	1,755	KP	244	3,866	2	16.7	1	1
50	NAM HEUNG	2	4,901	LFB	1,106	5,462	2	99.8	2	2
51	HUAI NAM SOM	2	1,072	LFB	152	2,422	1	10.7	1	1
54	HUAI LUANG	2	4,090	LFB	830	15,617	3	118.5	2	2
55	HUAI MONG	2	2,700	LFB	545	10,959	2	74.1	2	2
57	NAM SUAI	2	1,247	LFB	277	7,159	2	57.8	2	2
58	NAM LOEI	2	4,012	LFB	639	10,796	2	68.3	2	2
64	NAM KAM	2	3,495	KP	754	16,090	3	99.9	2	2
67	HUAI SOM PAK	2	2,516	AMR	584	7,974	2	45.9	1	2
68	HUAI BANG SAI	2	1,367	KP	255	1,768	1	14.2	1	1
70	HUAI BANG I	2	1,496	KP	243	3,930	2	14.1	1	1
73	H.BANG KOI	2	3,313	KP	658	9,015	2	50.2	1	2
75	SE BANG NOUAN	2	3,048	AMR	870	4,656	2	279.7	3	2
76	HUAI KHAMOUAN	2	3,762	KP	618	11,313	2	36.8	1	1
79	HUAI TOMO	2	2,611	BP	615	6,272	2	48.0	1	2
80	TONLE REPON	2	2,379	KP	309	883	1	51.6	2	2
85	O TALAS	2	1,448	NTS	254	292	1	41.5	2	1
88	ST.CHIKRENG	2	2,714	NTS	778	4,731	2	586.8	3	3
89	ST.SIEM REAP	2	3,619	NTS	892	21,733	3	586.0	3	3
90	ST.STAUNG	2	4,357	NTS	1,070	7,952	2	575.7	3	3
92	PREK PREAH	2	2,400	KM	462	765	1	49.4	2	2
93	ST.SANGKER	2	2,344	CM	530	5,527	2	481.1	3	3
94	ST.BATTAMBANG	2	3,708	CM	1,207	13,392	2	491.2	3	3
95	TONLE SAP	2	2,744	TS	325	606	1	43,918.8	3	3
96	PREK KRIENG	2	3,332	KM	911	2,088	1	134.3	2	2
97	ST.DAUNTRI	2	3,696	CM	892	10,973	2	499.6	3	3
99	PREK KAMP	2	1,142	KM	309	1,304	1	47.6	2	2
100	PREK TE	2	4,364	VU	1,189	5,077	2	1,680.8	3	3
	GRAND TOTAL		624,654			**2,186,258**		**105,102.2**		

8.1.3 Small tributaries

Of the small tributaries, the H. Ma Hiao, H. Khok, Nam Mang Ngai and Huai Bang Lieng all score moderately highly on consumption based estimates, but these are all tributaries associated with higher population densities.

The only small tributary to score highly on a surface area estimate of yield is the B. Khai San, followed by Doi Luang Pae Muang, Nam Thon, Huaag Hua, Huai Muk and Prek Mun. None of these rivers contribute significantly to the overall yield of the tributaries of the LMB.

Table 8-3: Significance groupings for fish yield estimates for small tributaries

Code	Tributary	Size category	Catchment area	Geological zone	Total length	Total yield of fish from 5 km corridor	Total yield of fish from 5 km corridor	Potential yield of resident fish/year	Potential yield of resident fish/km/year	% of total resident fish yield in LMB
			sq km		km	Tonnes/yr	scaled	Tonnes/yr	scaled	scaled
9	B.KHAI SAN	1	778	NH	73	2,501	1	55.8	3	2
10	NAM KEUNG	1	633	NH	52	975	1	1.5	1	1
13	DOI LUANG PAE MUANG	1	688	NH	125	910	1	10.9	2	1
14	NAM NGAM	1	489	NH	68	1,654	1	2.4	1	1
17	NAM MAE NGAO	1	485	NH	69	1,245	1	4.3	1	1
30	NAM NHAH	1	316	NH	63	61	1	3.6	1	1
33	MUANG LIEP	1	488	NH	66	203	1	3.2	1	1
34	NAM TON	1	587	NH	107	241	1	4.3	1	1
36	NAM THONG	1	455	NH	129	849	1	7.8	1	1
37	NAM KADUN	1	456	AMR	83	2,380	1	3.7	1	1
40	NAM PHONE	1	664	NH	101	1,183	1	5.1	1	1
41	B.NAM SONG	1	138	NH	4	116	1		-	-
43	H.SOPHAY	1	186	NH	85	406	1	6.8	1	1
44	NAM THON	1	838	AMR	243	1,008	1	21.5	2	1
45	PHU LUONG YOT HUAI DUA	1	491	NH	54	73	1	0.1	1	1
46	NAM KAI	1	602	NH	71	644	1	4.4	1	1
49	H.MA HIAO	1	990	NH	136	4,839	2	8.7	1	1
52	HOAAG HUA	1	626	AMR	131	505	1	11.1	2	1
53	PHU PA HUAK	1	132	LFB	26	501	1	0.6	1	1
56	H. KHOK	1	538	LFB	131	3,819	2	9.0	1	1
61	NAM MANG NGAI	1	944	AMR	169	3,708	2	7.1	1	1
62	HUAI THUAI	1	739	KP	142	2,859	1	10.1	1	1
63	HUAI HO	1	691	KP	136	3,418	1	8.8	1	1
65	HUAI BANG HAAK	1	938	KP	159	5,927	2	9.4	1	1
69	HUAI MUK	1	792	KP	145	3,218	1	14.4	2	1
78	HUAI BANG LIENG	1	695	BP	206	2,861	1	13.6	1	1
84	PREK MUN	1	476	KP	121	968	1	10.3	2	1
	GRAND TOTAL		624,654			**2,186,258**		**105,102.2**		

9 Assessing the tributaries with the least modification

Three different sets of parameters have been used to identify the degree of modification of the tributaries. These are:

- **Population** measured as:
  - Population density of the catchment
  - Population density by stream length based on the populations living within 5 km of all of the stream orders.
  - Urban population
  - Percentage of the catchment occupied by urban areas
- **Land use change** in the catchment. A Landuse Change Index has been derived which sums the percentage of the catchment under different forms of agriculture (paddy rice cultivation, field crops, swidden, fruit trees and plantations) plus percentage urban areas and dividing this by the percentage of forest land use. The concept behind this is that forest landuse is the most natural form of landuse (though degraded forests would be included in the estimates of forest landuse), and hence the lower the index the less modified is the catchment by other forms of landuse. For the overall LMB the LCI is 0.65. In the tables below, the dark green (3 scale) indicates the least modification.
- **Infrastructure development** in the catchment. This includes three different forms of infrastructure, roads, irrigation and hydropower. In order to bring them to a common basis for comparison, the different measures for each (river/road densities, % of irrigated area in the catchment, and installed capacity of existing and proposed large hydropower projects per kilometer of tributary) have been given a grade of 0 – 4 (based upon 0, 20th, 50th, and 80th percentiles). These indices have then been added to give the overall infrastructure index of the tributary.

9.1 Population

Population can be used as an indication of modification, in that higher densities of people living along the river are using it and modifying it through abstraction (water for drinking and irrigation) fisheries and extractive industries such as gold, sand and gravel. Urban populations also tend to modify the water quality through discharges of sewage and industrial effluents. Out of the total of 74.6 million people, nearly 60 million live within 5 km of the Mekong and its tributaries, within an overall population density of 119 persons per sq km of the catchments, and 496 persons per kilometer of river. About 12% of the population is classified as urban and 88% as rural.

9.1.1 Large tributaries

The large tributaries carrying the largest numbers of people per sq km of catchment or per kilometer of stream length include:

- Nam Mae Ing (by catchment) Northern Highlands
- Nam Songkhram (by length) and Nam Mun (by both catchment and length) Khorat Plateau
- Siem Bok (by both catchment and length) northern plains of Cambodian

- Stung Baribo (by catchment) and Prek Thnot (by both catchment and length) Cardamon mountains
- Delta (by both catchment and length)

The large tributaries with the highest proportions of urban populations include Stung Baribo and Prek Thnot, whilst those with the lowest proportions of rural populations include the Se San.

Table 9-1: Significance groupings for populations of large tributaries

Code	Tributary	Size category	Geological zone	Catchment area	Stream length	Total population	Population within 5 km of tributary	Population density	Density by stream length	Urban		Rural		% urban area in catchment
				sq km	km	Number	Number	Persons/ sq km (scaled)	Persons/ km (scaled)	Number	% in catchment (scaled)	Number	% in catchment (scaled 1=100%)	% (scaled)
1	NAM OU	3	NH	26,033	5,740	640,156	495,670	1	1	113,952	2	526,204	2	1
3	NAM THA	3	NH	8,918	1,029	235,631	173,614	1	1	24,436	1	211,195	2	1
5	NAM MAE KOK	3	NH	10,701	1,833	875,217	712,502	2	2	154,037	2	721,180	2	2
6	NAM SUONG	3	NH	6,578	1,070	90,955	83,557	1	1			90,955	1	
15	NAM KHAN	3	NH	7,490	1,454	225,074	177,748	1	1	33,911	2	191,163	2	1
16	NAM MAE ING	3	NH	7,267	1,682	985,423	893,627	3	2	78,256	1	907,167	2	2
24	NAM NGUM	3	NH	16,906	3,365	862,538	769,322	1	1	66,755	1	795,783	2	1
29	NAM CADINH	3	AMR	14,822	2,981	58,420	52,215	1	1	5,426	1	52,994	2	1
42	NAM SONGKHRAM	3	KP	13,123	2,759	1,777,881	1,719,208	2	3			1,777,881	1	
59	SE BANG FAI	3	AMR	10,407	1,583	340,754	306,798	1	1			340,754	1	
60	NAM CHI	3	KP	49,133	9,303	8,145,051	6,369,241	3	3	962,814	1	7,182,237	2	2
66	SE BANG HIENG	3	AMR	19,958	5,114	774,096	755,897	1	1			774,096	1	
71	SE KONG	3	KM	28,815	4,932	356,559	308,070	1	1	28,268	1	328,291	2	1
72	NAM MUN	3	KP	70,574	12,192	12,506,284	9,442,456	3	3	1,568,241	1	10,938,043	2	2
74	SE DONE	3	AMR	7,229	2,249	510,260	409,284	2	1	99,954	2	410,306	2	1
77	SE SAN	3	KM	18,888	2,785	980,585	679,443	2	2	251,316	2	729,269	3	1
81	ST.SRENG	3	NTS	9,986	2,091	417,881	370,056	1	1			417,881	1	
82	ST. SEN	3	NTS	16,360	3,182	484,708	457,317	1	1	10,527	1	474,181	2	1
83	ST.MONGKOL BOREY	3	NTS	14,966	3,171	1,660,488	1,439,263	2	2	113,106	1	1,547,382	2	2
86	SRE POK	3	KM	30,942	6,729	2,373,197	1,930,660	2	2	312,866	1	2,060,331	2	1
87	SIEM BOK	3	NTS	8,851	2,258	1,258,415	1,128,177	3	3	45,339	1	1,213,076	2	1
91	ST.CHINIT	3	NTS	8,237	1,748	713,513	626,811	2	2			713,513	1	
98	ST.PURSAT	3	CM	5,965	1,597	313,747	310,104	2	1	3,643	1	310,104	2	1
101	ST.BARIBO	3	CM	7,154	2,192	1,475,725	1,001,986	3	2	470,281	3	1,005,444	3	1
102	PREK CHHLONG	3	VU	5,957	1,713	213,025	213,025	1	1			213,025	1	
103	DELTA	3	D	48,235	5,467	23,869,292	19,457,772	3	3	2,133,537	1	21,735,755	2	2
104	PREK THNOT	3	CM	6,124	1,740	1,782,359	1,060,797	3	3	665,255	3	1,117,104	3	2
	GRAND TOTAL			624,654	120,333	74,550,162	59,730,306	119.3	496.4	8,998,350	12.1	65,551,812	87.9	

9.1.2 Medium tributaries

Of the medium tributaries, those with the highest population densities include:

- H. Bang Bot and Nam Kam (by both catchment and length) on the Khorat Plateau,
- Huai Luang, Huai Mong, Nam Suai of LFB
- Stung Siem Reap (by both catchment and length) from the northern plains draining into the Tonle Sap

The medium tributaries with the highest percentages of urban populations and lowest percentage of rural populations include:

- Nam Mae Kham, Nam Sing, Nam Huong, Nam Nuao, Nam Phuong, Nam Nhiep, Nam Sane from the Northern Highlands
- Huai Luang from LFB
- Huai Som Pak in the Annamites
- Stung Battambang from the Cardamon mountains.

Table 9-2: Significance groupings for populations in medium tributaries

Code	Tributary	Size category	Geological zone	Catchment area	Stream length	Total population	Population within 5 km of tributary	Population density	Density by stream length	Urban		Rural		% urban area in catchment
				sq km	km	Number	Number	Persons/ sq km (scaled)	Persons/ km (scaled)	Number	% in catchment (scaled)	Number	% in catchment (scaled 1=100%)	% (scaled)
2	NAM NUAO	2	NH	2,287	259	71,670	38,465	1	1	21,185	2	50,485	3	2
4	NAM MA	2	NH	1,141	110	14,088	12,523	1	1			14,088	1	
7	NAM PHO	2	NH	2,855	395	18,233	17,111	1	1			18,233	1	
8	NAM MAE KHAM	2	NH	4,079	1,046	474,126	322,215	2	2	148,277	3	325,849	3	3
11	NAM NGAOU	2	NH	1,495	193	42,747	38,861	1	1			42,747	1	
12	NAM BENG	2	NH	2,131	176	99,044	83,302	1	2			99,044	1	
18	NAM KHOP	2	NH	1,521	345	25,643	25,208	1	1			25,643	1	
19	NAM TAM	2	NH	1,548	217	20,535	17,483	1	1			20,535	1	
20	NAM NAGO	2	NH	1,008	220	22,716	22,716	1	1			22,716	1	
21	NAM SING	2	NH	2,681	438	46,820	20,970	1	1	23,662	3	23,158	3	1
22	NAM PHUONG	2	NH	4,139	417	220,289	159,532	2	2	44,680	2	175,609	3	1
23	NAM NGEUN	2	NH	1,819	323	108,998	100,228	2	2			108,998	1	
25	NAM HOUNG	2	NH	2,872	556	106,388	64,177	1	1	40,163	3	66,225	3	2
26	NAM NHIEP	2	NH	4,577	707	57,934	37,276	1	1	16,718	2	41,216	3	1
27	NAM PHOUL	2	NH	2,095	348	86,070	84,277	1	2			86,070	1	
28	NAM SANE	2	NH	2,226	443	34,032	23,487	1	1	9,893	2	24,139	3	1
31	NAM NHIAM	2	NH	1,990	265	35,439	33,962	1	1			35,439	1	
32	NAM MANG	2	NH	1,836	425	37,780	37,780	1	1			37,780	1	
35	NAM SANG	2	NH	1,290	109	9,685	5,534	1	1			9,685	1	
38	H.BANG BOT	2	KP	2,402	462	371,910	371,910	3	3			371,910	1	
39	NAM MI	2	NH	1,032	83	17,461	17,461	1	1			17,461	1	
47	NAM HINBOUN	2	AMR	2,529	421	69,620	63,905	1	1			69,620	1	
48	H.NAM HUAI	2	KP	1,755	244	124,375	120,821	2	2			124,375	1	
50	NAM HEUNG	2	LFB	4,901	1,106	172,619	170,679	1	1			172,619	1	
51	HUAI NAM SOM	2	LFB	1,072	152	79,675	75,691	2	2			79,675	1	
54	HUAI LUANG	2	LFB	4,090	830	852,056	488,019	3	2	323,563	3	528,493	3	3
55	HUAI MONG	2	LFB	2,700	545	372,517	342,475	3	3	24,103	1	348,414	2	2
57	NAM SUAI	2	LFB	1,247	277	257,123	223,709	3	3	26,454	1	230,669	2	3
58	NAM LOEI	2	LFB	4,012	639	401,218	337,379	2	2	33,245	1	367,973	2	2
64	NAM KAM	2	KP	3,495	754	599,034	502,803	3	3	80,193	1	518,841	2	2
67	HUAI SOM PAK	2	AMR	2,516	584	325,961	230,451	2	2	88,358	2	237,603	3	2
68	HUAI BANG SAI	2	KP	1,367	255	60,210	55,238	1	1	3,986	1	56,224	2	1
70	HUAI BANG I	2	KP	1,496	243	136,983	122,812	2	2			136,983	1	
73	H.BANG KOI	2	KP	3,313	658	294,592	281,718	2	2			294,592	1	
75	SE BANG NOUAN	2	AMR	3,048	870	140,426	134,578	1	1	5,848	1	134,578	2	1
76	HUAI KHAMOUAN	2	KP	3,762	618	363,665	326,957	2	2	2,516	1	361,149	2	1
79	HUAI TOMO	2	BP	2,611	615	185,552	181,262	2	2			185,552	1	
80	TONLE REPON	2	KP	2,379	309	23,024	20,931	1	1			23,024	1	
85	O TALAS	2	NTS	1,448	254	6,927	6,927	1	1			6,927	1	
88	ST.CHIKRENG	2	NTS	2,714	778	116,330	112,115	1	1			116,330	1	
89	ST.SIEM REAP	2	NTS	3,619	892	639,310	515,011	3	3	100,942	2	538,368	2	1
90	ST.STAUNG	2	NTS	4,357	1,070	206,507	188,426	2	1			206,507	1	
92	PREK PREAH	2	KM	2,400	463	19,688	18,138	1	1	1,550	1	18,138	2	1
93	ST.SANGKER	2	CM	2,344	530	130,980	130,980	2	2			130,980	1	
94	ST.BATTAMBANG	2	CM	3,708	1,207	417,759	317,340	2	2	96,517	2	321,242	3	1
95	TONLE SAP	2	TS	2,744	325	14,349	14,349	1	1			14,349	1	
96	PREK KRIENG	2	KM	3,332	911	49,479	49,479	1	1			49,479	1	
97	ST.DAUNTRI	2	CM	3,696	891	270,424	260,029	2	2	3,205	1	267,219	2	1
99	PREK KAMP	2	KM	1,142	309	30,891	30,891	1	1			30,891	1	
100	PREK TE	2	VU	4,364	1,189	124,503	120,302	1	1	2,893	1	121,610	2	1
	GRAND TOTAL			624,654	120,333	74,550,162	59,730,306	119.3	496.4	8,998,350	12.1	65,551,812	87.9	

9.1.3 Small tributaries

Interestingly the small tributaries show the highest population densities usually both for catchment and stream length, and these include:

- B. Khai San, Nam Ngam, B. Nam Song, Huai Ma Hiao in the Northern Highlands
- Phu Pa Huak and H. Khok in the LFB
- Huai Thuai, Huai Ho, Huai Bang Haak and Huai Muk in the Khorat Plateau
- Nam Kadun, Nam Mang Ngai in Annamites

Those with the highest percentage of urban populations and lowest rural populations include:

- Doi Luang Pae Muang, H. Ma Hiao (Vientiane) in Northern Highlands
- Phu Pa Huak, H. Khok in the LFB
- Huai Ho and Huai Muk in the Khorat Plateau
- Nam Mang Ngai in the Annamites

This pattern is also reflected in the highest proportions of urban areas in the catchment.

Table 9-3: Significance groupings for populations in small tributaries

Code	Tributary	Size category	Geological zone	Catchment area	Stream length	Total population	Population within 5 km of tributary	Population density	Density by stream length	Urban		Rural		% urban area in catchment
				sq km	km	Number	Number	Persons/ sq km (scaled)	Persons/ km (scaled)	Number	% in catchment (scaled)	Number	% in catchment (scaled 1=100%)	% (scaled)
9	B.KHAI SAN	1	NH	778	73	74,360	72,294	2	3			74,360	1	
10	NAM KEUNG	1	NH	633	52	30,891	28,165	1	2			30,891	1	
13	DOI LUANG PAE MUANG	1	NH	688	125	36,638	28,448	2	1	7,784	2	28,854	3	2
14	NAM NGAM	1	NH	489	68	65,503	47,816	2	3	6,782	1	58,721	2	3
17	NAM MAE NGAO	1	NH	485	69	38,897	38,897	2	2			38,897	1	
30	NAM NHAH	1	NH	316	63	1,770	1,770	1	1			1,770	1	
33	MUANG LIEP	1	NH	488	66	5,861	5,861	1	1			5,861	1	
34	NAM TON	1	NH	587	107	6,966	6,966	1	1			6,966	1	
36	NAM THONG	1	NH	455	129	24,546	24,546	2	1			24,546	1	
37	NAM KADUN	1	AMR	456	83	80,080	68,794	3	3	9,320	1	70,760	2	2
40	NAM PHONE	1	NH	664	101	34,180	34,180	2	2			34,180	1	
41	B.NAM SONG	1	NH	138	4	3,340	3,340	1	3			3,340	1	
43	H.SOPHAY	1	NH	186	85	12,693	12,693	2	1			12,693	1	
44	NAM THON	1	AMR	838	243	29,147	29,147	1	1			29,147	1	
45	PHU LUONG YOT HUAI DU	1	NH	491	54	2,101	2,101	1	1			2,101	1	
46	NAM KAI	1	NH	602	71	19,428	18,619	1	2			19,428	1	
49	H.MA HIAO	1	NH	990	136	672,821	139,845	3	3	525,125	3	147,696	3	3
52	HOAAG HUA	1	AMR	626	131	14,595	14,595	1	1			14,595	1	
53	PHU PA HUAK	1	LFB	132	26	35,495	15,653	3	3	19,842	3	15,653	3	3
56	H. KHOK	1	LFB	538	131	166,997	119,341	3	3	44,067	2	122,930	3	3
61	NAM MANG NGAI	1	AMR	944	169	169,607	107,165	3	3	54,199	3	115,408	3	3
62	HUAI THUAI	1	KP	739	142	89,342	89,342	2	3			89,342	1	
63	HUAI HO	1	KP	691	136	159,480	106,809	3	3	49,111	3	110,369	3	3
65	HUAI BANG HAAK	1	KP	938	159	188,943	185,209	3	3			188,943	1	
69	HUAI MUK	1	KP	792	145	140,995	100,565	3	3	37,033	2	103,962	3	3
78	HUAI BANG LIENG	1	BP	695	206	87,897	82,681	2	2	5,216	1	82,681	2	2
84	PREK MUN	1	KP	476	121	22,950	22,950	1	1			22,950	1	
	GRAND TOTAL			624,654	120,333	74,550,162	59,730,306	119.3	496.4	8,998,350	12.1	65,551,812	87.9	

9.2 Land use in the catchment

The pattern of landuse in the catchments of the tributaries of the Mekong is shown in Figure 9-1

9.2.1 Large tributaries

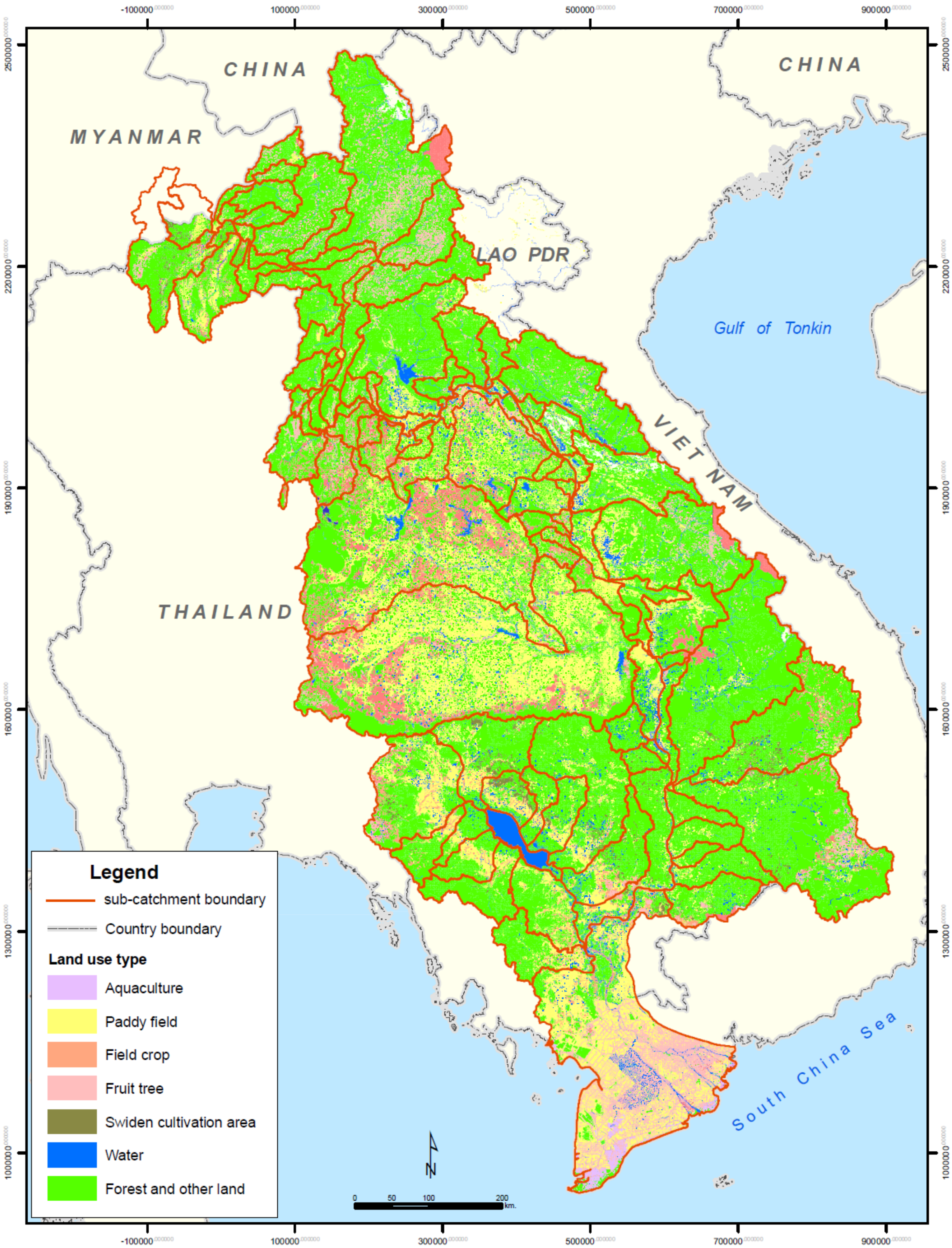
The large tributaries which have the highest forest cover in the catchment are:

- Nam Tha, Nam Khan in the Northern Highlands
- Nam Cadinh in the Annamites
- Se Kong from the Central Highlands

Those which have the highest proportion of paddy areas in the catchment include:

- Nam Mae Ing
- Nam Songkhram
- Nam Chi and Nam Mun
- Stung Mongkol Borey
- Delta

Figure 9-1: Distribution of land use in the sub-catchments of the Mekong



Those with the highest proportions of swidden in the catchment are those in the Northern Highlands – Nam Ou, Nam Tha, Nam Mae Kok and Nam Suong and Stung Sreng in the North of Cambodia.

Field crops are highest in Nam Songkhram, Nam Chi and Nam Mun and Stung Mongkol Borey.

Fruit trees and plantations are highest are found in the Nam Songkhram, Sre Pok, and the Delta.

The tributaries with the highest percentages of urban areas are the Nam Mae Kok, Nam Mae Ing, Nam Chi, Nam Mun, Stung Mongkol Borey, Delta and Prek Thnot.

Overall the large tributaries with the lowest ratio of other land uses to forest, i.e. the least modification are:

- Nam Ou, Nam Tha, Nam Suong, Nam Khan and Nam Ngum in the Northern Highlands
- Nam Cadinh, Se Bang Fai, Se Bang Hieng in the Annamites
- Se Kong, Se San and Sre Pok
- Stung Sen and Stung Pursat
- Prek Chhlong

The most highly modified catchments are:

- Nam Songkhram, Nam Chi, Nam Mun
- Stung Mongkol Borey
- Delta

Table 9-4: Significance groupings for land use modification in catchments of large tributaries

Code	Tributary	Size category	Catchment area	Geological zone	Forest area	% Forest in catchment	% of Total Forest in LMB	% Paddy in catchment	% Paddy in LMB	Swidden	Field crop	Fruit trees	Urban	Land use modification index
			sq km		sq.km	%	%	%	%	% of catchment	% of catchment	% of catchment	% in catchment	ratio of % other landuse to forest
1	NAM OU	3	26,033	NH	23,108	2	3	1	2	3	1		1	3
3	NAM THA	3	8,918	NH	8,460	3	3	1	1	3	1		1	3
5	NAM MAE KOK	3	10,701	NH	4,577	1	2	2	2	3	2	2	2	2
6	NAM SUONG	3	6,578	NH	6,007	2	3	1	1	3	1			3
15	NAM KHAN	3	7,490	NH	7,144	3	3	1	1	2	1		1	3
16	NAM MAE ING	3	7,267	NH	3,579	1	2	3	3	2	2	2	2	2
24	NAM NGUM	3	16,906	NH	14,862	2	3	1	3	2	1		1	3
29	NAM CADINH	3	14,822	AMR	14,139	3	3	1	2	2	1		1	3
42	NAM SONGKHRAM	3	13,123	KP	4,937	1	2	3	3		3	3		1
59	SE BANG FAI	3	10,407	AMR	7,956	1	3	2	2	1	1	0		3
60	NAM CHI	3	49,133	KP	12,837	1	3	3	3	1	3	1	2	1
66	SE BANG HIENG	3	19,958	AMR	16,998	2	3	2	3	2	1			3
71	SE KONG	3	28,815	KM	27,400	3	3	1	2	1	1	1	1	3
72	NAM MUN	3	70,574	KP	14,791	1	3	3	3	1	3	1	2	1
74	SE DONE	3	7,229	AMR	5,530	1	3	2	3	1	2		1	2
77	SE SAN	3	18,888	KM	16,709	2	3	1	2	2	2	1	1	3
81	ST.SRENG	3	9,986	NTS	6,913	1	3	2	3	3	1			2
82	ST. SEN	3	16,360	NTS	13,605	2	3	2	3	2	1	1	1	3
83	ST.MONGKOL BOREY	3	14,966	NTS	6,858	1	3	3	3	1	3	2	2	1
86	SRE POK	3	30,942	KM	26,487	2	3	1	2	1	2	3	1	3
87	SIEM BOK	3	8,851	NTS	5,591	1	3	2	3	2	2	1	1	2
91	ST.CHINIT	3	8,237	NTS	5,213	1	3	2	3	2	2	2		2
98	ST.PURSAT	3	5,965	CM	4,838	2	2	2	2	1	1		1	3
101	ST.BARIBO	3	7,154	CM	4,350	1	2	2	3	1	2		1	2
102	PREK CHHLONG	3	5,957	VU	5,040	2	3	1	2	2	2	2		3
103	DELTA	3	48,235	D	5,217	1	3	3	3	1	2	3	2	1
104	PREK THNOT	3	6,124	CM	4,216	1	2	2	3		2	1	2	2
	GRAND TOTAL		624,654		**343,647**	**55.01**		**23.51**		**1.56**	**6.98**	**2.38**	**1.59**	**0.65**

9.2.2 Medium tributaries

Many of the medium tributaries have amongst the highest scale of forest cover in the LMB, especially those in the Northern Highlands:

- Nam Pho, Nam Ngaou, Nam Khop, Nam Tam, Nam Nago, Nam Sing, Nam Phuong, Nam Ngeun, Nam Houng, Nam Nhiep, Nam Sane, Nam Nhiam, Nam Mang
- O Talas
- Prek Preah, Prek Krieng and Prek Kamp

By contrast those which have the highest proportions of agricultural land include:

For rice paddy:

- H. Bang Bot, Nam Kam, H. Bang Koi on the Khorat Plateau
- Huai Luang, Huai Mong and Nam Suai in LFB
- Stung Siem Reap and Stung Dauntri flowing into the Tonle Sap

For swidden, Nam Nuao, Nam Ma, Nam Mae Kham, Nam Beng, Nam Mi and Nam Sang in the Northern Highlands, and Nam Heung in the LFB, and the Stung Siem Reap in the north of the Tonle Sap.

For field crops the medium tributaries with the highest proportion include the H. Nam Huai, Nam Heung, Huai Nam Som, Huai Luang, Huai Mong and Nam Loei of LFB, and Huai Bang Sai and Huai Bang I from the Khorat Plateau.

For fruit trees and plantations, the medium sized tributaries with the highest proportions include H. Bang Bot and H.Nam Huai on the Khorat Plateau, and the Nam Loei in LFB.

The medium tributaries with the highest proportions of urban areas include Nam Mae Kham (Chiang Saen), and Huai Luang and Nam Suai in LFB.

The tributaries with the lowest landuse modification index include:

- Nam Ma, Nam Pho, Nam Ngaou, Nam Beng, Nam Khop, Nam Tam, Nam Nago, Nam Sing, Nam Phuong, Nam Ngeun, Nam Houng, Nam Nhiep, Nam Phoul, Nam Sane, Nam Nhiam, Nam Mang, Nam Sang, Nam Mi from Northern Highlands
- Nam Hinboun from the Annamites
- Huai Tomo from the Bolevan Plateau
- Tonle Repon from the southern edge of the Khorat Plateau and O Talas
- Prek Preah, Prek Krieng, Prek Kamp and Prek Te from the Kontum Massif and Volcanic Uplands.

The medium sized tributaries with the highest degree of landuse modification include:

- Nam Mae Kham
- Huai Bang Bot and Huai Bang I from Khorat Plateau
- Huai Nam Som, Huai Luang, Huai Mong, Nam Suai and Nam Loei from LFB
- Stung Siem Reap from the Tonle Sap tributaries

The Tonle Sap Great Lake is excluded because it does not have designated landuse or forest cover, apart from flooded forest.

Table 9-5: Significance groupings for land use modification in catchments of medium tributaries

Code	Tributary	Size category	Catchment area	Geological zone	Forest area	% Forest in catchment	% of Total Forest in LMB	% Paddy in catchment	% Paddy in LMB	Swidden	Field crop	Fruit trees	Urban	Land use modification index
			sq km		sq.km	%	%	%	%	% of catchment	% of catchment	% of catchment	% in catchment	ratio of % other landuse to forest
2	NAM NUAO	2	2,287	NH	1,943	2	2	1	1	3	2		2	2
4	NAM MA	2	1,141	NH	1,066	2	1	1	1	3				3
7	NAM PHO	2	2,855	NH	2,755	3	2	1	1	2				3
8	NAM MAE KHAM	2	4,079	NH	809	1	1	2	2	3	1	1	3	1
11	NAM NGAOU	2	1,495	NH	1,444	3	1	1	1	2				3
12	NAM BENG	2	2,131	NH	1,974	2	2	1	1	3				3
18	NAM KHOP	2	1,521	NH	1,459	3	1	1	1	2				3
19	NAM TAM	2	1,548	NH	1,475	3	1	1	1	2				3
20	NAM NAGO	2	1,008	NH	970	3	1	1	1	2				3
21	NAM SING	2	2,681	NH	2,531	3	2	1	1	2	1		1	3
22	NAM PHUONG	2	4,139	NH	3,876	3	2	1	1	2	1		1	3
23	NAM NGEUN	2	1,819	NH	1,707	3	2	1	1	2				3
25	NAM HOUNG	2	2,872	NH	2,792	3	2	1	1	2			2	3
26	NAM NHIEP	2	4,577	NH	4,415	3	2	1	1	2			1	3
27	NAM PHOUL	2	2,095	NH	1,936	2	2	1	1	1				3
28	NAM SANE	2	2,226	NH	2,138	3	2	1	1	1	1		1	3
31	NAM NHIAM	2	1,990	NH	1,909	3	2	1	1	2				3
32	NAM MANG	2	1,836	NH	1,765	3	2	1	1	2				3
35	NAM SANG	2	1,290	NH	1,170	2	1	1	1	3				3
38	H.BANG BOT	2	2,402	KP	925	1	1	3	3		2	31		1
39	NAM MI	2	1,032	NH	921	2	1	1	1	3	1			3
47	NAM HINBOUN	2	2,529	AMR	1,536	1	1	1	2	2	1			3
48	H.NAM HUAI	2	1,755	KP	983	1	1	1	1		3	3		2
50	NAM HEUNG	2	4,901	LFB	3,142	1	2	1	2	3	3	2		2
51	HUAI NAM SOM	2	1,072	LFB	420	1	1	2	1		3	1		1
54	HUAI LUANG	2	4,090	LFB	1,127	1	1	3	3		3	1	3	1
55	HUAI MONG	2	2,700	LFB	885	1	1	3	2		3	1	2	1
57	NAM SUAI	2	1,247	LFB	419	1	1	3	2		2	1	3	1
58	NAM LOEI	2	4,012	LFB	1,484	1	1	2	2	1	3	3	2	1
64	NAM KAM	2	3,495	KP	2,278	1	2	3	3		2	2	2	2
67	HUAI SOM PAK	2	2,516	AMR	1,653	1	1	2	2	1	1		2	2
68	HUAI BANG SAI	2	1,367	KP	966	1	1	1	1		3	1	1	2
70	HUAI BANG I	2	1,496	KP	617	1	1	2	2		3	2		1
73	H.BANG KOI	2	3,313	KP	1,742	1	2	3	3	0	2	1		2
75	SE BANG NOUAN	2	3,048	AMR	2,493	2	2	2	2				1	2
76	HUAI KHAMOUAN	2	3,762	KP	2,504	1	2	2	2	1	1		1	2
79	HUAI TOMO	2	2,611	BP	2,078	1	2	2	2	2	1			3
80	TONLE REPON	2	2,379	KP	2,225	2	2	1	1	2	1			3
85	O TALAS	2	1,448	NTS	1,428	3	1	1	1	1	1			3
88	ST.CHIKRENG	2	2,714	NTS	1,713	1	2	2	2	2	1			2
89	ST.SIEM REAP	2	3,619	NTS	1,116	1	1	3	3	3	2		1	1
90	ST.STAUNG	2	4,357	NTS	2,849	1	2	2	2	2	1	1		2
92	PREK PREAH	2	2,400	KM	2,276	3	2	1	1	1	1	1	1	3
93	ST.SANGKER	2	2,344	CM	721	1	1	2	2	1	1			2
94	ST.BATTAMBANG	2	3,708	CM	2,768	1	2	2	2	1	2	1	1	2
95	TONLE SAP	2	2,744	TS	2									0
96	PREK KRIENG	2	3,332	KM	3,119	3	2	1	1	1	1	1		3
97	ST.DAUNTRI	2	3,696	CM	1,824	1	2	3	3	1	2		1	2
99	PREK KAMP	2	1,142	KM	1,095	3	1	1	1		1	1		3
100	PREK TE	2	4,364	VU	4,052	2	2	1	2	1	1	1	1	3
	GRAND TOTAL		624,654		343,647	55.01		23.51		1.56	6.98	2.38	1.59	0.65

9.2.3 Small tributaries

Of the small tributaries, the Nam Nhah from the Northern Highlands has the highest proportion of forest cover.

The H. Ma Hiao from the Northern Highlands, the Huai Khok in the LFB, and the Huai Thuai, Huai Ho, Huai Bang Haak and Huai Muk from the Khorat Plateau have the highest proportion of paddy in the catchment.

The small tributaries with the highest proportion of swidden are the Doi Luang Pae Muang, Nam Ngam and Nam Mae Ngao, Nam Ton, Nam Phone, B. Nam Song, Phu Luong Yot Huai Du and Nam Kai in the Northern Highlands, the Nam Thon in the Annamites.

The small tributaries with the highest proportions of field crops are the Phu Pa Huak and Huai Khok from the LFB, the Huai Muk from the Khorat Plateau and Huai Bang Lieng from the Bolevan Plateau.

The small tributaries with the highest proportion of fruit trees and plantations are the Phu Pa Huak from the LFB and Huai Bang Haak from the Khorat Plateau.

The small tributaries with the highest proportion of urban areas are the Nam Ngam, H. Ma Hiao, in the Northern Highlands, the Phu Pa Huak, Huai Khok in the LFB, the Nam Mang Ngai in the Annamites, Huai Ho and Huai Muk in the Khorat Plateau.

Overall the small tributaries with the least landuse change are:

- B. Khai San and Nam Keung, Nam Nhah, Muang Liep, Nam Thong, Nam Phone, B.Nam Song, H. Sophay, Phu Luong Yot Du and Nam Kai in the Northern Highlands
- Nam Thon in the Annamites
- Prek Mun from the Khorat Plateau

Those which have the highest landuse change include:

- H.Ma Hiao, from Northern Highlands
- Phu Pa Huak and Huai Khok from LFB
- Huai Thuai, Huai Ho, Huai Bang Haak and Huai Muk from the Khorat Plateau

Table 9-6: Significance groupings for land use modification in catchments of small tributaries

Code	Tributary	Size category	Catchment area	Geological zone	Forest area	% Forest in catchment	% of Total Forest in LMB	% Paddy in catchment	% Paddy in LMB	Swidden	Field crop	Fruit trees	Urban	Land use modification index
			sq km		sq.km	%	%	%	%	% of catchment	% of catchment	% of catchment	% in catchment	ratio of % other landuse to forest
9	B.KHAI SAN	1	778	NH	661	2	1	2	1	2	1			3
10	NAM KEUNG	1	633	NH	582	2	1	1	1	2	1			3
13	DOI LUANG PAE MUANG	1	688	NH	338	1	1	2	1	3	2	1	2	2
14	NAM NGAM	1	489	NH	422	2	1	1	1	3			3	2
17	NAM MAE NGAO	1	485	NH	280	1	1	1	1	3	2	2		2
30	NAM NHAH	1	316	NH	309	3	1	1	1	1				3
33	MUANG LIEP	1	488	NH	454	2	1	1	1	2				3
34	NAM TON	1	587	NH	486	2	1	1	1	3				2
36	NAM THONG	1	455	NH	371	2	1	1	1	1				3
37	NAM KADUN	1	456	AMR	258	1	1	2	1	1			2	2
40	NAM PHONE	1	664	NH	573	2	1	1	1	3				3
41	B.NAM SONG	1	138	NH	115	2	1	1	1	3	2			3
43	H.SOPHAY	1	186	NH	125	1	1	2	1	1				3
44	NAM THON	1	838	AMR	734	2	1	1	1	2	1			3
45	PHU LUONG YOT HUAI DU	1	491	NH	417	2	1	1	1	3	1			3
46	NAM KAI	1	602	NH	515	2	1	1	1	3				3
49	H.MA HIAO	1	990	NH	407	1	1	3	2	1	1		3	1
52	HOAAG HUA	1	626	AMR	501	2	1	2	1	2	1			2
53	PHU PA HUAK	1	132	LFB	64	1	1	2	1		3	3	3	1
56	H. KHOK	1	538	LFB	171	1	1	3	2		3	2	3	1
61	NAM MANG NGAI	1	944	AMR	552	1	1	2	2		1		3	2
62	HUAI THUAI	1	739	KP	338	1	1	3	2		2	2		1
63	HUAI HO	1	691	KP	252	1	1	3	2		1	2	3	1
65	HUAI BANG HAAK	1	938	KP	244	1	1	3	2		2	3		1
69	HUAI MUK	1	792	KP	229	1	1	3	2		3	2	3	1
78	HUAI BANG LIENG	1	695	BP	557	2	1	1	1	1	3		2	2
84	PREK MUN	1	476	KP	348	1	1	2	1	1	1			3
	GRAND TOTAL		624,654		**343,647**	**55.01**		**23.51**		**1.56**	**6.98**	**2.38**	**1.59**	**0.65**

9.3 Infrastructure modification

The parameters for infrastructure modification include river/road density index, irrigated areas and the existing and proposed installed capacity of hydropower per kilometre of river length. Note that the road data is somewhat old and therefore does not include more up to date road developments, whilst the hydropower data also includes proposed dams on the tributaries.

9.3.1 Large tributaries

The large tributaries that will be the most modified by infrastructure in decreasing order of infrastructure index:

- Se Kong, Se San, for the intensity of hydropower development, irrigation and road development
- Nam Cadinh for the intensity of hydropower development and road development and Se Bang Fai for high intensity of irrigation
- Prek Chhlong and the Delta for high intensity of irrigation
- Nam Ngum for hydropower development, Nam Songkhram for irrigation, Stung Sen, Sre Pok for hydropower, irrigation and roads development and Siem Bok for irrigation and roads development

Table 9-7: Significance groupings for infrastructure development in large tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	Irrigated area	% of catchment	% of irrigated area in LMB	Large Hydropower (existing and proposed)			River/Road density	Road dev index	Irrigation intensity index	Hydropower index	Infrastructure index
			sq km	km		sq km	%	%	No of HPP	MW	MW/km					
1	NAM OU	3	26,033	5,740	NH	7	0.03	0.010	13	1,272	0.22	3.52	1	0	3	4
3	NAM THA	3	8,918	1,029	NH	16	0.18	0.024	1	168	0.16	1.99	2	0	2	4
5	NAM MAE KOK	3	10,701	1,833	NH						0.00	6.09	1	0	0	1
6	NAM SUONG	3	6,578	1,070	NH				2	174	0.16	3.94	1	0	2	3
15	NAM KHAN	3	7,490	1,454	NH	1	0.01	0.002	3	289	0.20	4.36	1	0	2	3
16	NAM MAE ING	3	7,267	1,682	NH						0.00	3.23	2	0	0	2
24	NAM NGUM	3	16,906	3,365	NH	1	0.05	0.002	10	1,628	0.48	2.75	2	0	4	6
29	NAM CADINH	3	14,822	2,981	AMR				7	2,230	0.75	4.75	1	0	4	5
42	NAM SONGKHRAM	3	13,123	2,759	KP	6	3.07	0.009			0.00	2.48	2	3	0	5
59	SE BANG FAI	3	10,407	1,583	AMR	7,523	15.31	11.297	2	141	0.09	1.18	3	4	1	8
60	NAM CHI	3	49,133	9,303	KP	37	3.91	0.056	3	67	0.01	2.72	2	3	0	5
66	SE BANG HIENG	3	19,958	5,114	AMR	49	1.96	0.074	4	141	0.03	1.12	4	2	1	7
71	SE KONG	3	28,815	4,932	KM	11,268	15.97	16.921	20	2,688	0.55	1.72	3	4	4	11
72	NAM MUN	3	70,574	12,192	KP	59	1.79	0.089	3	672	0.06	2.25	2	2	1	5
74	SE DONE	3	7,229	2,249	AMR	19	0.63	0.029	5	200	0.09	2.30	2	1	1	4
77	SE SAN	3	18,888	2,785	KM	9	1.33	0.014	12	2,570	0.92	2.29	2	2	4	8
81	ST.SRENG	3	9,986	2,091	NTS	162	0.99	0.243			0.00	1.07	4	1	0	5
82	ST. SEN	3	16,360	3,182	NTS	916	6.12	1.375	1	38	0.01	1.16	3	3	1	7
83	ST.MONGKOL BOREY	3	14,966	3,171	NTS	1	0.13	0.001			0.00	1.35	3	0	0	3
86	SRE POK	3	30,942	6,729	KM	158	1.79	0.238	11	1,095	0.16	3.33	2	2	2	6
87	SIEM BOK	3	8,851	2,258	NTS	249	9.19	0.374	-	-	0.00	1.28	3	3	0	6
91	ST.CHINIT	3	8,237	1,748	NTS						0.00	0.99	4	0	0	4
98	ST.PURSAT	3	5,965	1,597	CM				2	110	0.07	1.51	3	0	1	4
101	ST.BARIBO	3	7,154	2,192	CM						0.00	0.94	4	0	0	4
102	PREK CHHLONG	3	5,957	1,713	VU	35,613	73.83	53.481			0.00	1.49	3	4	0	7
103	DELTA	3	48,235	5,467	D	355	5.79	0.533			0.00	0.59	4	3	0	7
104	PREK THNOT	3	6,124	1,740	CM						0.00	1.12	4	0	0	4
	GRAND TOTAL		624,654	120,333		**66,590**	10.66	100	**136**	**15,700**	0.13	1.70				

9.3.2 Medium tributaries

The medium tributaries that will be most modified by infrastructure include:

- Nam Nhiep for its hydropower development
- Nam Hinboun for roads, irrigation and hydropower,
- Nam Ngeun, H. Nam Huai, H.Som Pak, Nam Kam for roads and irrigation
- Huai Khamouan, Tonle Repon for roads and irrigation
- Stung Siem Reap, Stung Chikreng and Stung Dauntri for roads and irrigation
- Prek Krieng and Prek Te for roads and irrigation

Table 9-8: Significance groupings for infrastructure development in medium tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	Irrigated area	% of catchment	% of irrigated area in LMB	Large Hydropower (existing and proposed)			River/Road density	Road dev index	Irrigation intensity index	Hydropower index	Infrastructure index
			sq km	km		sq km	%	%	No of HPP	MW	MW/km					
2	NAM NUAO	2	2,287	259	NH	15	0.67	0.023			0.00	2.15	2	1	0	3
4	NAM MA	2	1,141	110	NH	2	0.20	0.003	1	5	0.05	1.26	3	0	1	4
7	NAM PHO	2	2,855	395	NH	3	0.10	0.004	1	-	0.00	5.36	1	0	0	1
8	NAM MAE KHAM	2	4,079	1,046	NH						0.00	15.24	1	0	0	1
11	NAM NGAOU	2	1,495	193	NH						0.00	2.04	2	0	0	2
12	NAM BENG	2	2,131	176	NH	14	0.65	0.021	1	30	0.17	1.17	3	1	2	6
18	NAM KHOP	2	1,521	345	NH				1	-	0.00	2.59	2	0	0	2
19	NAM TAM	2	1,548	217	NH						0.00	2.07	2	0	0	2
20	NAM NAGO	2	1,008	220	NH	1	0.05	0.002			0.00	1696.35	1	0	0	1
21	NAM SING	2	2,681	438	NH	8	0.18	0.011	2	129	0.29	16.51	1	0	3	4
22	NAM PHUONG	2	4,139	417	NH	10	0.55	0.015	6	74	0.18	2.67	2	1	2	5
23	NAM NGEUN	2	1,819	323	NH	361	2.14	0.542			0.00	1.58	3	3	0	6
25	NAM HOUNG	2	2,872	556	NH	14	0.30	0.020			0.00	2.55	2	0	0	2
26	NAM NHIEP	2	4,577	707	NH	12	0.57	0.018	6	477	0.67	2.74	2	1	4	7
27	NAM PHOUL	2	2,095	348	NH	15	0.66	0.022	1	-	0.00	2.06	2	1	0	3
28	NAM SANE	2	2,226	443	NH	15	0.10	0.023	3	146	0.33	2.34	2	0	3	5
31	NAM NHIAM	2	1,990	265	NH	4	0.24	0.007	1	-	0.00	1.56	2	0	0	2
32	NAM MANG	2	1,836	425	NH				2	100	0.24	21.20	1	0	3	4
35	NAM SANG	2	1,290	109	NH	6	1.37	0.009			0.00	10.50	1	2	0	3
38	H.BANG BOT	2	2,402	462	KP	13	1.28	0.020			0.00	1.77	3	2	0	5
39	NAM MI	2	1,032	83	NH						0.00	1.03	4	0	0	4
47	NAM HINBOUN	2	2,529	421	AMR	30	1.73	0.046	2	58	0.14	1.24	3	2	2	7
48	H.NAM HUAI	2	1,755	244	KP	161	16.28	0.242			0.00	1.58	3	4	0	7
50	NAM HEUNG	2	4,901	1,106	LFB	56	5.27	0.085			0.00	2.89	2	3	0	5
51	HUAI NAM SOM	2	1,072	152	LFB	6	0.90	0.008			0.00	4.66	1	1	0	2
54	HUAI LUANG	2	4,090	830	LFB	222	8.21	0.333			0.00	3.17	2	3	0	5
55	HUAI MONG	2	2,700	545	LFB	149	27.72	0.224			0.00	4.10	1	4	0	5
57	NAM SUAI	2	1,247	277	LFB	163	4.06	0.245			0.00	2.09	2	3	0	5
58	NAM LOEI	2	4,012	639	LFB	207	1.99	0.311			0.00	2.51	2	2	0	4
64	NAM KAM	2	3,495	754	KP	149	15.90	0.224	1	6	0.01	2.54	2	4	0	6
67	HUAI SOM PAK	2	2,516	584	AMR	59	4.34	0.089			0.00	0.58	4	3	0	7
68	HUAI BANG SAI	2	1,367	255	KP	37	4.64	0.055			0.00	15.11	1	3	0	4
70	HUAI BANG I	2	1,496	243	KP	64	0.22	0.096			0.00	2.63	2	0	0	2
73	H.BANG KOI	2	3,313	658	KP	155	2.14	0.232	1	-	0.00	4.12	1	3	0	4
75	SE BANG NOUAN	2	3,048	870	AMR	129	3.42	0.193	1	-	0.00	3.41	1	3	0	4
76	HUAI KHAMOUAN	2	3,762	618	KP	221	1.17	0.331	1	-	0.00	0.69	4	2	0	6
79	HUAI TOMO	2	2,611	615	BP				1	-	0.00	0.84	4	0	0	4
80	TONLE REPON	2	2,379	309	KP	107	1.07	0.161			0.00	0.87	4	2	0	6
85	O TALAS	2	1,448	254	NTS	424	1.37	0.637			0.00	1.97	2	2	0	4
88	ST.CHIKRENG	2	2,714	778	NTS	301	8.32	0.452			0.00	1.94	3	3	0	6
89	ST.SIEM REAP	2	3,619	892	NTS	266	6.11	0.400			0.00	0.84	4	3	0	7
90	ST.STAUNG	2	4,357	1,070	NTS	76	0.92	0.114			0.00	1.41	3	1	0	4
92	PREK PREAH	2	2,400	463	KM	206					0.00	1.99	2	0	0	2
93	ST.SANGKER	2	2,344	530	CM	145	8.77	0.218			0.00	1.55	3	3	0	6
94	ST.BATTAMBANG	2	3,708	1,207	CM				2	46	0.04	1.88	3	0	1	4
95	TONLE SAP	2	2,744	325	TS		3.91	0.000			0.00		0	3	0	3
96	PREK KRIENG	2	3,332	911	KM	443	11.97	0.665			0.00	1.66	3	4	0	7
97	ST.DAUNTRI	2	3,696	891	CM	152	2.54	0.228			0.00	0.92	4	3	0	7
99	PREK KAMP	2	1,142	309	KM						0.00	1.45	3	0	0	3
100	PREK TE	2	4,364	1,189	VU	147	5.79	0.220			0.00	1.65	3	3	0	6
	GRAND TOTAL		624,654	120,333		**66,590**	10.66	100	**136**	**15,700**	0.13	1.70				

9.3.3 Small tributaries

The small tributaries with the highest infrastructure modification include:

- Nam Kadun, Hoaag Hua, Phu Pa Huak, for roads and irrigation development
- Huai Khok, Huai Thuai, Huai Ho for intensity of irrigation development
- Nam Ngam, Huai Khok, Nam Mang Ngai, Huai Tuai, Huai Ho and Huai Muk for roads and irrigation development
- None of the small tributaries are influenced by large scale hydropower development.

Table 9-9: Significance groupings for infrastructure development in small tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	Irrigated area	% of catchment	% of irrigated area in LMB	Large Hydropower (existing and proposed)			River/Road density	Road dev index	Irrigation intensity index	Hydropower index	Infrastructure index
			sq km	km		sq km	%	%	No of HPP	MW	MW/km					
9	B.KHAI SAN	1	778	73	NH	2	0.22	0.003			0.00		0	0	0	0
10	NAM KEUNG	1	633	52	NH						0.00		0	0	0	0
13	DOI LUANG PAE MUANG	1	688	125	NH						0.00	24.76	1	0	0	1
14	NAM NGAM	1	489	68	NH	12	2.54	0.019			0.00	1.46	3	3	0	6
17	NAM MAE NGAO	1	485	69	NH						0.00		0	0	0	0
30	NAM NHAH	1	316	63	NH						0.00		0	0	0	0
33	MUANG LIEP	1	488	66	NH	1	0.20	0.002			0.00	2.62	2	0	0	2
34	NAM TON	1	587	107	NH	3	0.23	0.005			0.00	57.66	1	0	0	1
36	NAM THONG	1	455	129	NH	37	8.12	0.056			0.00	3.39	2	3	0	5
37	NAM KADUN	1	456	83	AMR	383	15.95	0.576			0.00	0.42	4	4	0	8
40	NAM PHONE	1	664	101	NH						0.00	1.28	3	0	0	3
41	B.NAM SONG	1	138	4	NH	3,220	24.54	4.836			0.00	0.15	1	4	0	5
43	H.SOPHAY	1	186	85	NH	6	0.69	0.009			0.00	4.96	1	1	0	2
44	NAM THON	1	838	243	AMR						0.00	1.56	3	0	0	3
45	PHU LUONG YOT HUAI DU	1	491	54	NH				1	-	0.00	10.98	1	0	0	1
46	NAM KAI	1	602	71	NH	35	1.39	0.053			0.00	1.19	3	2	0	5
49	H.MA HIAO	1	990	136	NH	31	0.63	0.046			0.00	0.40	4	1	0	5
52	HOAAG HUA	1	626	131	AMR	21	15.94	0.032			0.00	0.64	4	4	0	8
53	PHU PA HUAK	1	132	26	LFB	604	14.78	0.908			0.00	0.58	4	4	0	8
56	H. KHOK	1	538	131	LFB	200	16.01	0.300			0.00	1.92	3	4	0	7
61	NAM MANG NGAI	1	944	169	AMR	59	7.98	0.089			0.00	0.61	4	3	0	7
62	HUAI THUAI	1	739	142	KP	74	10.73	0.111			0.00	2.23	2	4	0	6
63	HUAI HO	1	691	136	KP	594	16.99	0.892			0.00	1.47	3	4	0	7
65	HUAI BANG HAAK	1	938	159	KP	238	1.19	0.357			0.00	1.53	3	2	0	5
69	HUAI MUK	1	792	145	KP	43	2.91	0.065			0.00	1.73	3	3	0	6
78	HUAI BANG LIENG	1	695	206	BP	9	0.35	0.014	1	-	0.00	2.40	2	1	0	3
84	PREK MUN	1	476	121	KP						0.00	1.39	3	0	0	3
	GRAND TOTAL		624,654	120,333		**66,590**	10.66	100	**136**	**15,700**	0.13	1.70				

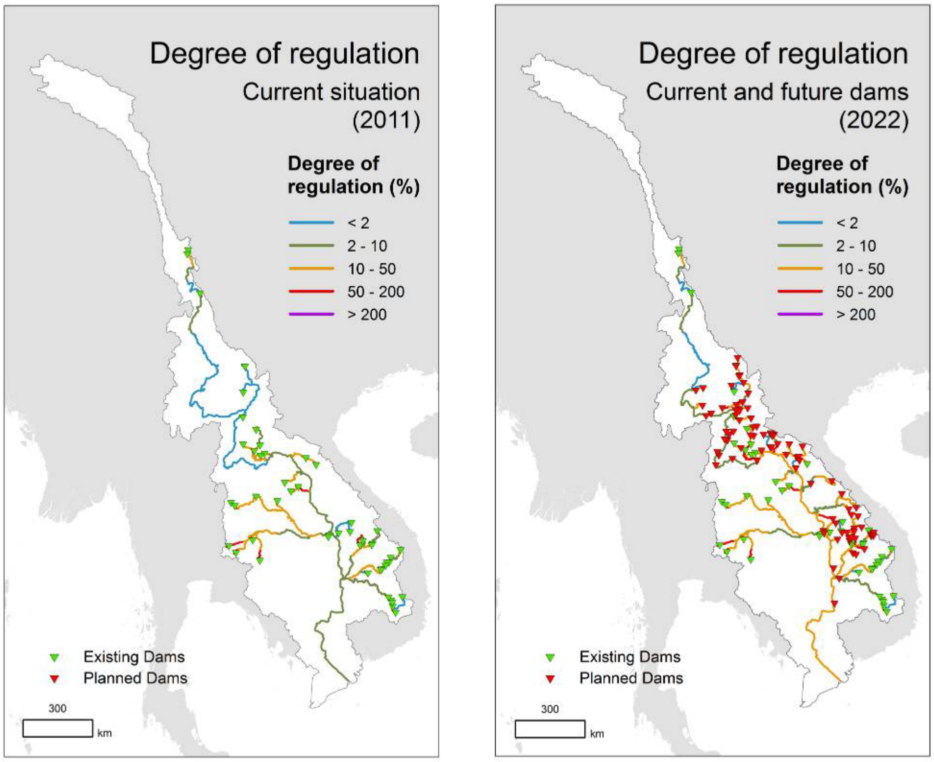
9.4 Changes in degree of regulation

Lehner et al (2011) have also estimated the degree of regulation of the Mekong by large dams. Figure 9-2 shows the degree of regulation downstream of dams for each river reach of the MRB (for an interpretation of the %-levels see section 2.4.1). The left panel shows an assessment of flow regulation based on the 50 existing large dams considered by our model in 2011 (a combination of dams from the global GRanD database and data provided by MRC). Many dams show a large DOR directly downstream of their location; the highest reaching 276% for the Houayho Dam on the Xekong River. Further downstream, DOR values can decline if increased inflows from unimpeded tributaries "dilute" the flow regulation effect; while they can increase where the effects multiple dams coincide.

The results show that the cumulative impacts of all existing dams on flow regulation extend far downstream along the river network, with a current DOR of 4.4% in the Mekong Delta. In the future scenario on the right panel, several new tributaries would be affected if all 84 planned dams were constructed, and DOR values would increase significantly in many already regulated reaches. In particular, the values increase along the Mekong main stem, and the degree of regulation more than doubles to 9.8% in the Mekong Delta.

The total network flow regulation (netDOR) is currently at 1.99%. It should be noted that this value is calculated as an average for the entire habitat volume of the river network, including sections upstream of dams where no flow regulation occurs. The absolute value is thus dependent on the extent of the river network and should not be interpreted in the same way as the DOR for single reaches. However, in terms of relative change, the netDOR value increases to 5.45% if all 84 future dams were built, more than double the extent of current network flow regulation.

Figure 9-2: Degree of regulation downstream of dams for today (2011) and a future scenario (2022) if 84 new dams were built.



10 Assessing Ecological significance

The variability and complexity of the foregoing parameters shows how difficult it is to define the ecological significance of the Mekong tributaries. There are probably as many different assessments of significance as there are tributaries and each tributary might have a claim to be more significant than the others.

This section attempts to pull together the different indicators in order to compare and contrast the different tributaries in terms of four aspects –

- Ecological Diversity,
- Ecological Uniqueness
- Ecosystem Productivity
- Degrees of Modification (Least and Greatest).

A number of the different parameters considered individually above have been graded to highlight only the most significant. These parameters have been grouped according to Physical, Geological, Ecological, Biodiversity and Fish, Productivity and Modification.

The assessments are done visually to highlight the different aspects of significance. The descriptions identify the tributaries of significance and the reasons for this significance.

10.1 Ecological diversity

For ecological diversity, the important physical parameters are stream density, slope, the highest elevations of the source of the tributary and the greatest range of elevation. In terms of ecological character the key the parameters chosen are the ecological diversity index, the proportion of forest in the catchment, the tributaries with the greatest proportion of natural wetlands. In terms of biodiversity and fish, the important parameters are the fish species diversity, the percentage of migratory species and the biodiversity interest.

10.1.1 Large tributaries

In terms of Physical parameters, the Nam Ou, Nam Ngum , Se Kong, Stung Pursat and Stung Baribo have the combination of arising at high elevations, with high stream density, slope and elevation range, which would point towards greatest ecological diversity. However of these, Nam Ou does not score highly on ecological or biodiversity parameters.

For high Ecological diversity in combination with the physical parameters, the Nam Ngum, Se Kong and Stung Baribo stand out. It is clear that the highest forested catchments are in the Northern Highlands including Nam Tha, Nam Khan, Nam Cadinh, and Se Kong.

Of the tributaries that do not have high elevations or wide elevation ranges, the Nam Chi, the Sre Pok and the Delta score most highly in ecological diversity, wetlands and fish species diversity. It is clear that the tributaries with the highest proportion of migratory fish and the highest biodiversity interest come lower down in the Mekong Basin and include the Se San, Stung Sen, Stung Pursat and Prek Chhlong.

Table 10-1: Comparing significant parameters to assess ecological diversity for large tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	**Physical Parameters**	Stream density	Greatest Slope	Highest elevation of source	Greatest Elevation range	**Ecological character**	Ecological diversity index	Highest Forested areas in catchment	Greatest % of natural wetlands	**Biodiversity and Fish**	Fish species diversity	Migratory fish species %	Biodiversity interest (PAs and KBAs)
			sq km	km														
1	NAM OU	3	26,033	5,740	NH													
3	NAM THA	3	8,918	1,029	NH													
5	NAM MAE KOK	3	10,701	1,833	NH													
6	NAM SUONG	3	6,578	1,070	NH													
15	NAM KHAN	3	7,490	1,454	NH													
16	NAM MAE ING	3	7,267	1,682	NH													
24	NAM NGUM	3	16,906	3,365	NH													
29	NAM CADINH	3	14,822	2,981	AMR													
42	NAM SONGKHRAM	3	13,123	2,759	KP													
59	SE BANG FAI	3	10,407	1,583	AMR													
60	NAM CHI	3	49,133	9,303	KP													
66	SE BANG HIENG	3	19,958	5,114	AMR													
71	SE KONG	3	28,815	4,932	KM													
72	NAM MUN	3	70,574	12,192	KP													
74	SE DONE	3	7,229	2,249	AMR													
77	SE SAN	3	18,888	2,785	KM													
81	ST.SRENG	3	9,986	2,091	NTS													
82	ST. SEN	3	16,360	3,182	NTS													
83	ST.MONGKOL BOREY	3	14,966	3,171	NTS													
86	SRE POK	3	30,942	6,729	KM													
87	SIEM BOK	3	8,851	2,258	NTS													
91	ST.CHINIT	3	8,237	1,748	NTS													
98	ST.PURSAT	3	5,965	1,597	CM													
101	ST.BARIBO	3	7,154	2,192	CM													
102	PREK CHHLONG	3	5,957	1,713	VU													
103	DELTA	3	48,235	5,467	D													
104	PREK THNOT	3	6,124	1,740	CM													

10.1.2 Medium tributaries

Similar patterns can be seen for ecological diversity amongst the medium tributaries. There is a grouping of high physical parameters amongst the Northern Highlands tributaries, with most of the rivers showing the greatest slopes high elevations of the source and a wide elevation range. Amongst these the Nam Nuao, Nam Tam, Nam Nhiep and Nam Sane stand out. As is to be expected from such highland rivers there is also a grouping of Northern Highlands rivers with highest forest areas in the catchment. Very few of these rivers also have a high ecological zone diversity index, the one exception being the Nam Mae Kham which also has a predicted high migratory fish percentage. Only Nam Phuong has a predicted high fish species diversity.

Most of the medium rivers from the Khorat Plateau and LFB have the greatest percentage of natural wetlands in their catchments, as would be expected from catchments that have a relatively flat topography. Only the Nam Heung has a wide elevation range and high ecological zone diversity. Nam

Leoi has a predicted high fish species diversity and the Huai Bang Koi has high ecological zone diversity, high percentage of natural wetlands and high predicted fish species diversity.

From the Annamites, the Se Bang Nouan stands out as having high stream density, high ecological zone diversity, a high percentage of migratory fish species and an indication of high biodiversity interest.

The medium tributaries lower down the LMB also exhibit similarities, especially in the rivers flowing into the Tonle Sap having high stream densities, whether they arise north of the Tonle Sap, from the Cardamon mountains or the 4P rivers flowing into the left bank of the Mekong. The Stung Battambang stands out amongst these rivers having highest elevation range, high ecological zone diversity, high migratory fish species and high biodiversity interest. Stung Sangker also has high ecological zone diversity a high percentage of natural wetlands and high migratory fish percentage.

The Tonle Sap is a very different type of catchment, with no terrestrial forest (apart from flooded forest) and an exceptionally high fish species diversity, but lower percentage of migratory fish. Although the whole of the Tonle Sap lies in a Biosphere Reserve, the actual percentage of protected areas within the catchment is relatively small.

Of the 4P rivers, Prek Krieng and Prek Te have high ecological zone diversity, while Prek Preah, Prek Krieng and Prek Kamp have a high percentage of forest in the catchment. They do not have high natural wetlands. Prek Krieng, Prek Kamp and Prek Te have high migratory fish percentage. They all have high areas of biodiversity interest.

Table 10-2: Comparing significant parameters to assess ecological diversity for medium tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	**Physical Parameters**	Stream density	Greatest Slope	Highest elevation of source	Greatest Elevation range	**Ecological character**	Ecological diversity index	Highest Forested areas in catchment	Greatest % of natural wetlands	**Biodiversity and Fish**	Fish species diversity	Migratory fish species %	Biodiversity interest (PAs and KBAs)
			sq km	km														
2	NAM NUAO	2	2,287	259	NH													
4	NAM MA	2	1,141	110	NH													
7	NAM PHO	2	2,855	395	NH													
8	NAM MAE KHAM	2	4,079	1,046	NH													
11	NAM NGAOU	2	1,495	193	NH													
12	NAM BENG	2	2,131	176	NH													
18	NAM KHOP	2	1,521	345	NH													
19	NAM TAM	2	1,548	217	NH													
20	NAM NAGO	2	1,008	220	NH													
21	NAM SING	2	2,681	438	NH													
22	NAM PHUONG	2	4,139	417	NH													
23	NAM NGEUN	2	1,819	323	NH													
25	NAM HOUNG	2	2,872	556	NH													
26	NAM NHIEP	2	4,577	707	NH													
27	NAM PHOUL	2	2,095	348	NH													
28	NAM SANE	2	2,226	443	NH													
31	NAM NHIAM	2	1,990	265	NH													
32	NAM MANG	2	1,836	425	NH													
35	NAM SANG	2	1,290	109	NH													
38	H.BANG BOT	2	2,402	462	KP													
39	NAM MI	2	1,032	83	NH													
47	NAM HINBOUN	2	2,529	421	AMR													
48	H.NAM HUAI	2	1,755	244	KP													
50	NAM HEUNG	2	4,901	1,106	LFB													
51	HUAI NAM SOM	2	1,072	152	LFB													
54	HUAI LUANG	2	4,090	830	LFB													
55	HUAI MONG	2	2,700	545	LFB													
57	NAM SUAI	2	1,247	277	LFB													
58	NAM LOEI	2	4,012	639	LFB													
64	NAM KAM	2	3,495	754	KP													
67	HUAI SOM PAK	2	2,516	584	AMR													
68	HUAI BANG SAI	2	1,367	255	KP													
70	HUAI BANG I	2	1,496	243	KP													
73	H.BANG KOI	2	3,313	658	KP													
75	SE BANG NOUAN	2	3,048	870	AMR													
76	HUAI KHAMOUAN	2	3,762	618	KP													
79	HUAI TOMO	2	2,611	615	BP													
80	TONLE REPON	2	2,379	309	KP													
85	O TALAS	2	1,448	254	NTS													
88	ST.CHIKRENG	2	2,714	778	NTS													
89	ST.SIEM REAP	2	3,619	892	NTS													
90	ST.STAUNG	2	4,357	1,070	NTS													
92	PREK PREAH	2	2,400	463	KM													
93	ST.SANGKER	2	2,344	530	CM													
94	ST.BATTAMBANG	2	3,708	1,207	CM													
95	TONLE SAP	2	2,744	325	TS													
96	PREK KRIENG	2	3,332	911	KM													
97	ST.DAUNTRI	2	3,696	891	CM													
99	PREK KAMP	2	1,142	309	KM													
100	PREK TE	2	4,364	1,189	VU													

10.1.3 Small tributaries

Similar patterns can be observed amongst the small tributaries, with those in the Northern Highlands tending to rise at higher elevations and with higher slopes. The Nam Ngam and the Nam Thong stand out as having higher physical diversity. Further south the Huai Bang Lieng arising from the Bolevan Plateau has high stream density, slope, elevation and wide elevation range, and high predicted migratory fish percentage. Prek Mun, flowing into the Mekong near Siphandone, has high stream density and slopes, high percentage of natural wetlands and high predicted migratory fish and high biodiversity interest.

Very few of the small tributaries have high forest percentages in the catchment, but those arising from the Khorat Plateau and LFB have high percentages of natural wetlands.

Of the small rivers that have high ecological zone diversity, the Phu Luong Yot Huai and H.Ma Hiao also have predicted high fish species diversity. From the Annamites, the Nam Thon has high stream density and high ecological zone diversity.

The small rivers from the eastern edge of the Khorat Plateau – Huai Bang Haak and Huai Muk – have high slope, high ecological zone diversity, high percentage of natural wetlands, and the Huai Bang Haak has high fish species diversity and the Huai Muk has a high biodiversity interest.

Table 10-3: Comparing significant parameters to assess ecological diversity small tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	**Physical Parameters**	Stream density	Greatest Slope	Highest elevation of source	Greatest Elevation range	**Ecological character**	Ecological diversity index	Highest Forested areas in catchment	Greatest % of natural wetlands	**Biodiversity and Fish**	Fish species diversity	Migratory fish species %	Biodiversity interest (PAs and KBAs)
			sq km	km														
9	B.KHAI SAN	1	778	73	NH													
10	NAM KEUNG	1	633	52	NH													
13	DOI LUANG PAE MUAN	1	688	125	NH													
14	NAM NGAM	1	489	68	NH													
17	NAM MAE NGAO	1	485	69	NH													
30	NAM NHAH	1	316	63	NH													
33	MUANG LIEP	1	488	66	NH													
34	NAM TON	1	587	107	NH													
36	NAM THONG	1	455	129	NH													
37	NAM KADUN	1	456	83	AMR													
40	NAM PHONE	1	664	101	NH													
41	B.NAM SONG	1	138	4	NH													
43	H.SOPHAY	1	186	85	NH													
44	NAM THON	1	838	243	AMR													
45	PHU LUONG YOT HUAI	1	491	54	NH													
46	NAM KAI	1	602	71	NH													
49	H.MA HIAO	1	990	136	NH													
52	HOAAG HUA	1	626	131	AMR													
53	PHU PA HUAK	1	132	26	LFB													
56	H. KHOK	1	538	131	LFB													
61	NAM MANG NGAI	1	944	169	AMR													
62	HUAI THUAI	1	739	142	KP													
63	HUAI HO	1	691	136	KP													
65	HUAI BANG HAAK	1	938	159	KP													
69	HUAI MUK	1	792	145	KP													
78	HUAI BANG LIENG	1	695	206	BP													
84	PREK MUN	1	476	121	KP													

10.2 Ecological uniqueness

The set of parameters that describe Ecological uniqueness include similar physical parameters, but instead of a wide elevation range, limited elevation range is chosen. The importance of limestone in defining a very specific type of aquatic ecology is highlighted under geological character. The parameter of Restricted Ecological Zone was defined by taking those tributaries that had a low ecological zone diversity index, and were restricted to only one ecological zone. The measure of greatest proportions of natural wetlands and presence of recognized important wetlands is also used to define uniqueness. Fish species diversity and percentage of endemic species and endangered species numbers as well as biodiversity interest complete the biodiversity and fish parameters defining uniqueness.

10.2.1 Large tributaries

Many large tributaries appear to qualify for the significance of ecological uniqueness. The Nam Ou is physically diverse but contains a high ecological zone restriction and endangered species. The Nam Mae Kok is significant in arising at a high elevation and having important wetlands, high fish diversity and high proportion of endemic species of fish. The Nam Mae Ing also has important wetlands, occurring at a more limited elevation range, with a high ecological zone restriction and high numbers of endemic fish species.

The large tributaries containing the highest limestone areas are the Nam Suong, Nam Khan Nam Cadinh and Se Bang Fai, and these are the tributaries that also have highest ecological zone restriction. Nam Ou and Nam Tha also in the Northern Highlands contain limestone and have high ecological zone restriction.

The Nam Songkhram, Nam Chi and Nam Mun stand out as tributaries with limited elevation range, high proportions of natural wetlands, presence of important wetlands, high fish species diversity and presence of endangered fish and other aquatic species.

The Se Kong, Se San and Sre Pok stand out as tributaries with important wetlands, high fish species diversity and presence of endangered fish species, but generally lower ecological restriction (i.e greater variation).

The Siem Bok catchment is ecologically unique in that it does not have a major tributary associated with it, but it falls in a limited elevation range, high ecological zone restriction, high proportion of wetlands and presence of important wetlands and presence of endangered fish species. Geomorphologically, Siem Bok is distinct because it forms the overland linkage for floodwaters passing from the Mekong to the Tonle Sap.

The Delta also forms an ecologically unique catchment with limited elevation range, a highly restricted ecological zone, high proportion of wetlands, presence of important wetlands, high fish species diversity and presence of endangered fish species.

Table 10-4: Comparing significant parameters to assess ecological uniqueness for large tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	**Physical Parameters**	Stream density	Greatest Slope	Highest elevation of source	Limited elevation range	**Geological character**	Greatest proportion of Limestone	**Ecological character**	Restricted Ecological zone	Greatest % of natural wetlands	Presence of important wetlands	**Biodiversity and Fish**	Fish species diversity	Endemic species %	Endangered fish species numbers	Endangered species	Biodiversity interest (PAs and KBAs)
			sq km	km																		
1	NAM OU	3	26,033	5,740	NH																	
3	NAM THA	3	8,918	1,029	NH																	
5	NAM MAE KOK	3	10,701	1,833	NH																	
6	NAM SUONG	3	6,578	1,070	NH																	
15	NAM KHAN	3	7,490	1,454	NH																	
16	NAM MAE ING	3	7,267	1,682	NH																	
24	NAM NGUM	3	16,906	3,365	NH																	
29	NAM CADINH	3	14,822	2,981	AMR																	
42	NAM SONGKHRAM	3	13,123	2,759	KP																	
59	SE BANG FAI	3	10,407	1,583	AMR																	
60	NAM CHI	3	49,133	9,303	KP																	
66	SE BANG HIENG	3	19,958	5,114	AMR																	
71	SE KONG	3	28,815	4,932	KM																	
72	NAM MUN	3	70,574	12,192	KP																	
74	SE DONE	3	7,229	2,249	AMR																	
77	SE SAN	3	18,888	2,785	KM																	
81	ST.SRENG	3	9,986	2,091	NTS																	
82	ST. SEN	3	16,360	3,182	NTS																	
83	ST.MONGKOL BOREY	3	14,966	3,171	NTS																	
86	SRE POK	3	30,942	6,729	KM																	
87	SIEM BOK	3	8,851	2,258	NTS																	
91	ST.CHINIT	3	8,237	1,748	NTS																	
98	ST.PURSAT	3	5,965	1,597	CM																	
101	ST.BARIBO	3	7,154	2,192	CM																	
102	PREK CHHLONG	3	5,957	1,713	VU																	
103	DELTA	3	48,235	5,467	D																	
104	PREK THNOT	3	6,124	1,740	CM																	

10.2.2 Medium tributaries

None of the medium tributaries with high elevations and slopes have a high proportion of their catchment in a limited elevation range. In the Northern Highlands, only the Nam Sang and Nam Mi are restricted in elevation ranges, whilst most of those in the LFB and those from the eastern edge of the Khorat Plateau all have limited elevation ranges. As noted before, these also tend to have high proportion of natural wetlands.

The medium tributaries with high proportions of limestone in the catchments are those from the Northern Highlands such as Nam Sing, Nam Phuong, Nam Houng, Nam Nhiep, Nam Phoul and Nam Sang. The only other high limestone medium sized river is the Nam Hinboun from the Annamites. Of these high limestone rivers, the Nam Sing, and Nam Sang and the Nam Hinboun are restricted to single ecological zones. The Nam Sang and Nam Phuong stand out because they also have a high predicted fish species diversity and the Nam Phuong has a high proportion of endemic fish species.

The medium rivers in the Northern Highlands which often have the greatest slopes are often also restricted to single ecological zones, and tend to have the highest proportions of Mekong endemic fish species. These include the Nam Nuao, Nam Ma, Nam Pho, Nam Ngaou and Nam Beng. The Nam Mae Kham stands out here for having high stream density and slope, presence of important wetlands and a predicted high proportion of endemic fish species.

Amongst the group of medium tributaries with a limited elevation range coming from the LFB and Khorat Plateau, many have high proportion of natural wetlands and the H.Bang Bot, Huai Mong, and Nam Kam have important wetland sites. Those with restricted ecological zones include Huai Nam Som, Nam Suai and the Huai Bang Sai and Huai Bang I. The H. Nam Huai and the Nam Loei and Huai Bang Koi have high fish species diversity and the presence of endangered fish species and other aquatic species.

None of the rivers flowing into Mekong around or below Khone Falls have a limited elevation range and only the Huai Tomo, Tonle Repon, O Talas flow through a single ecological zone, but these have a presence of important wetlands, endangered species and high biodiversity interest.

The Tonle Sap lies almost entirely within the Swamp forest ecological zone and in a Biosphere reserve, with the highest proportion of natural wetlands and presence of important wetlands. It also has very high fish diversity and presence of endangered fish species. The medium rivers flowing into the Tonle Sap with restricted ecological zones are the Stung Chikreng and Stung Siem Reap, and the Stung Chikreng also has important wetlands and areas of high biodiversity interest. Stung Battambang and Stung Dauntri also share some of characteristics with the other rivers flowing into the Tonle Sap.

Table 10-5: Comparing significant parameters to assess ecological uniqueness for medium tributaries

Code	Tributary	Size category	Catchment area (sq km)	Stream length (km)	Geological zone	**Physical Parameters**	Stream density	Greatest Slope	Highest elevation of source	Limited elevation range	**Geological character**	Greatest proportion of Limestone	**Ecological character**	Restricted ecological zone	Greatest % of natural wetlands	Presence of important wetlands	**Biodiversity and Fish**	Fish species diversity	Endemic species %	Endangered fish species numbers	Endangered species	Biodiversity interest (PAs and KBAs)
2	NAM NUAO	2	2,287	259	NH																	
4	NAM MA	2	1,141	110	NH																	
7	NAM PHO	2	2,855	395	NH																	
8	NAM MAE KHAM	2	4,079	1,046	NH																	
11	NAM NGAOU	2	1,495	193	NH																	
12	NAM BENG	2	2,131	176	NH																	
18	NAM KHOP	2	1,521	345	NH																	
19	NAM TAM	2	1,548	217	NH																	
20	NAM NAGO	2	1,008	220	NH																	
21	NAM SING	2	2,681	438	NH																	
22	NAM PHUONG	2	4,139	417	NH																	
23	NAM NGEUN	2	1,819	323	NH																	
25	NAM HOUNG	2	2,872	556	NH																	
26	NAM NHIEP	2	4,577	707	NH																	
27	NAM PHOUL	2	2,095	348	NH																	
28	NAM SANE	2	2,226	443	NH																	
31	NAM NHIAM	2	1,990	265	NH																	
32	NAM MANG	2	1,836	425	NH																	
35	NAM SANG	2	1,290	109	NH																	
38	H.BANG BOT	2	2,402	462	KP																	
39	NAM MI	2	1,032	83	NH																	
47	NAM HINBOUN	2	2,529	421	AMR																	
48	H.NAM HUAI	2	1,755	244	KP																	
50	NAM HEUNG	2	4,901	1,106	LFB																	
51	HUAI NAM SOM	2	1,072	152	LFB																	
54	HUAI LUANG	2	4,090	830	LFB																	
55	HUAI MONG	2	2,700	545	LFB																	
57	NAM SUAI	2	1,247	277	LFB																	
58	NAM LOEI	2	4,012	639	LFB																	
64	NAM KAM	2	3,495	754	KP																	
67	HUAI SOM PAK	2	2,516	584	AMR																	
68	HUAI BANG SAI	2	1,367	255	KP																	
70	HUAI BANG I	2	1,496	243	KP																	
73	H.BANG KOI	2	3,313	658	KP																	
75	SE BANG NOUAN	2	3,048	870	AMR																	
76	HUAI KHAMOUAN	2	3,762	618	KP																	
79	HUAI TOMO	2	2,611	615	BP																	
80	TONLE REPON	2	2,379	309	KP																	
85	O TALAS	2	1,448	254	NTS																	
88	ST.CHIKRENG	2	2,714	778	NTS																	
89	ST.SIEM REAP	2	3,619	892	NTS																	
90	ST.STAUNG	2	4,357	1,070	NTS																	
92	PREK PREAH	2	2,400	463	KM																	
93	ST.SANGKER	2	2,344	530	CM																	
94	ST.BATTAMBANG	2	3,708	1,207	CM																	
95	TONLE SAP	2	2,744	325	TS																	
96	PREK KRIENG	2	3,332	911	KM																	
97	ST.DAUNTRI	2	3,696	891	CM																	
99	PREK KAMP	2	1,142	309	KM																	

10.2.3 Small tributaries

Many of the small rivers have a limited elevation range as would be expected, and some of these are restricted to single ecological zones, such as B. Khai San, Doi Luang Pae Muang, Muang Liep and Nam Phone in the Northern Highlands, and Hoaag Hua in the Annamites and Huai Khok in the LFB.

The Nam Nhah stands out for having greatest slope, high proportion of limestone, and restricted ecological range. Other high limestone small tributaries include B. Nam Song, and Nam Mang Ngai.

Few of the small tributaries have high fish species diversity, but as before the tributaries with the highest proportion of endemic fish species occur in the Northern Highlands, with Nam Keung, Phu Luong Yot Huai and H. Ma Hiao also having high fish species diversity and high numbers of endangered fish species. H. Ma Hiao also has presence of important wetlands (That Luang marsh).

The small tributaries from Khorat Plateau have predicted high numbers of endangered fish species, but none of the small tributaries have recorded presence of other endangered aquatic species.

Table 10-6: Comparing significant parameters to assess ecological uniqueness for small tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	**Physical Parameters**	Stream density	Greatest Slope	Highest elevation of source	Limited elevation range	**Geological character**	Greatest proportion of Limestone	**Ecological character**	Restricted ecological zone	Greatest % of natural wetlands	Presence of important wetlands	**Biodiversity and Fish**	Fish species diversity	Endemic species %	Endangered fish species numbers	Endangered species	Biodiversity interest (PAs and KBAs)
			sq km	km																		
9	B.KHAI SAN	1	778	73	NH																	
10	NAM KEUNG	1	633	52	NH																	
13	DOI LUANG PAE MUAN	1	688	125	NH																	
14	NAM NGAM	1	489	68	NH																	
17	NAM MAE NGAO	1	485	69	NH																	
30	NAM NHAH	1	316	63	NH																	
33	MUANG LIEP	1	488	66	NH																	
34	NAM TON	1	587	107	NH																	
36	NAM THONG	1	455	129	NH																	
37	NAM KADUN	1	456	83	AMR																	
40	NAM PHONE	1	664	101	NH																	
41	B.NAM SONG	1	138	4	NH																	
43	H.SOPHAY	1	186	85	NH																	
44	NAM THON	1	838	243	AMR																	
45	PHU LUONG YOT HUAI	1	491	54	NH																	
46	NAM KAI	1	602	71	NH																	
49	H.MA HIAO	1	990	136	NH																	
52	HOAAG HUA	1	626	131	AMR																	
53	PHU PA HUAK	1	132	26	LFB																	
56	H. KHOK	1	538	131	LFB																	
61	NAM MANG NGAI	1	944	169	AMR																	
62	HUAI THUAI	1	739	142	KP																	
63	HUAI HO	1	691	136	KP																	
65	HUAI BANG HAAK	1	938	159	KP																	
69	HUAI MUK	1	792	145	KP																	
78	HUAI BANG LIENG	1	695	206	BP																	
84	PREK MUN	1	476	121	KP																	

10.3 Ecosystem Productivity

The productivity of the tributaries is measured principally through the different measures of fish productivity (based on consumption, area of water surface and as a comparative contribution to the total LMB fish production). These are then compared with stream density the proportion of floodplains and wetlands in the catchment, and the proportions of black fish, migratory fish and the migratory/blackfish ratio, which indicates the relative importance of migratory fish.

10.3.1 Large tributaries

It is clear that the large tributaries lower in the LMB have the highest fish productivity. The Nam Mun, Nam Chi and the Delta stand out as having the highest fish productivity on all three counts, followed by the tributaries feeding into the Tonle Sap – Stung Sreng, Stung Sen, Stung Mongkol Borey, Stung Chinit, Stung Baribo and Prek Thnot.

Of the more northern tributaries, the Nam Ngum and Nam Songkhram are important both in terms of fish production based upon consumption and for their comparative contribution to the LMB fish production, though less productive on an area basis. The same applies for Se Bang Hieng, Sre Pok, Siem Bok.

It is clear that the tributaries with the highest blackfish percentages and migratory fish percentages occur lower down in the LMB, largely matching the productivity. The tributaries that stand out are the Stung Sen, Siem Bok, Stung Baribo, Prek Chhlong and Prek Thnot.

The tributaries with a high migratory to blackfish ratio are concentrated in the northern part of the LMB, and include Nam Ou, Nam Mae Kok, Nam Suong, Nam Khan, Se Bang Fai, Se Kong, Se San and Sre Pok. This may indicate the relative importance of migratory fish in fish productivity.

Table 10-7: Comparing significant parameters to assess ecosystem productivity for large tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	**Physical Parameters**	Stream density	**Geological character**	Greatest proportions of Floodplains + wetlands	**Biodiversity and Fish**	Blackfish %	Migratory fish species %	Migratory/blackfish index	**Productivity**	Fish productivity (consumption)	Fish productivity (area of water body)	Fish production of total LMB
			sq km	km													
1	NAM OU	3	26,033	5,740	NH												
3	NAM THA	3	8,918	1,029	NH												
5	NAM MAE KOK	3	10,701	1,833	NH												
6	NAM SUONG	3	6,578	1,070	NH												
15	NAM KHAN	3	7,490	1,454	NH												
16	NAM MAE ING	3	7,267	1,682	NH												
24	NAM NGUM	3	16,906	3,365	NH												
29	NAM CADINH	3	14,822	2,981	AMR												
42	NAM SONGKHRAM	3	13,123	2,759	KP												
59	SE BANG FAI	3	10,407	1,583	AMR												
60	NAM CHI	3	49,133	9,303	KP												
66	SE BANG HIENG	3	19,958	5,114	AMR												
71	SE KONG	3	28,815	4,932	KM												
72	NAM MUN	3	70,574	12,192	KP												
74	SE DONE	3	7,229	2,249	AMR												
77	SE SAN	3	18,888	2,785	KM												
81	ST.SRENG	3	9,986	2,091	NTS												
82	ST. SEN	3	16,360	3,182	NTS												
83	ST.MONGKOL BOREY	3	14,966	3,171	NTS												
86	SRE POK	3	30,942	6,729	KM												
87	SIEM BOK	3	8,851	2,258	NTS												
91	ST.CHINIT	3	8,237	1,748	NTS												
98	ST.PURSAT	3	5,965	1,597	CM												
101	ST.BARIBO	3	7,154	2,192	CM												
102	PREK CHHLONG	3	5,957	1,713	VU												
103	DELTA	3	48,235	5,467	D												
104	PREK THNOT	3	6,124	1,740	CM												

10.3.2 Medium tributaries

The medium tributaries with the greatest productivity occur in the Tonle Sap and its influent rivers, Stung Chikreng, Stung Siem Reap, Stung Staung, Stung Sangker and Stung Dauntri. Only Stung Siem Reap with its high population density has a high estimate of productivity based upon consumption figures.

Further north the Huai Luang and Nam Kam also have high consumption based fish production figures, probably also because of the relatively high density of human populations[7]. The Nam Suai from the LFB and the Se Bang Nouan also have high productivity based upon estimated yields per area of water surface. Of these there does not appear to be a linkage with the tributaries that have greatest proportions of natural wetlands.

An analysis of the blackfish and migratory fish, shows that the Nam Mae Kham has predicted high proportions of both types of fish. The Nam Phuong has high proportions of black fish, but it is not until further south that the proportions of black fish are significant in the Huai Som Pak and Huai Tomo above Khone Falls, and in the Stung Battambang and Stung Dauntri, and in Prek Kamp and Prek Te.

High proportions of migratory fish are found in the Se Bang Nouan and in the tributaries of the Tonle Sap – St. Chikreng, St. Siem Reap, St. Staung, St. Sangker, St. Battambang and St. Dauntri, and in Prek Kamp and Prek Te. It is interesting that the Tonle Sap, which has the highest fish species diversity, does not have high proportions of either black or migratory fish.

The importance of migratory fish is shown by the high values of the migratory to black fish ratio, and only the tributaries in the Northern Highlands score highly. Nam Mae Kham with high proportions of both black and migratory fish does not score highly in this migratory to black fish ratio.

There appears to be a similar pattern for high fish productivity with high stream density, greatest proportions of natural wetlands, and high proportions of blackfish and migratory species in the Tonle Sap catchment, but this is not apparent for the medium tributaries on the Khorat Plateau and LFB.

[7] This illustrates the dangers of estimating fish productivity based upon human consumption

Table 10-8: Comparing significant parameters to assess ecosystem productivity for medium tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	**Physical Parameters**	Stream density	**Geological character**	Greatest proportions of Floodplains + wetlands	**Biodiversity and Fish**	Blackfish %	Migratory fish species %	Migratory/blackfish index	**Productivity**	Fish productivity (consumption)	Fish productivity (area of water body)	Fish production of total LMB
			sq km	km													
2	NAM NUAO	2	2,287	259	NH												
4	NAM MA	2	1,141	110	NH												
7	NAM PHO	2	2,855	395	NH												
8	NAM MAE KHAM	2	4,079	1,046	NH												
11	NAM NGAOU	2	1,495	193	NH												
12	NAM BENG	2	2,131	176	NH												
18	NAM KHOP	2	1,521	345	NH												
19	NAM TAM	2	1,548	217	NH												
20	NAM NAGO	2	1,008	220	NH												
21	NAM SING	2	2,681	438	NH												
22	NAM PHUONG	2	4,139	417	NH												
23	NAM NGEUN	2	1,819	323	NH												
25	NAM HOUNG	2	2,872	556	NH												
26	NAM NHIEP	2	4,577	707	NH												
27	NAM PHOUL	2	2,095	348	NH												
28	NAM SANE	2	2,226	443	NH												
31	NAM NHIAM	2	1,990	265	NH												
32	NAM MANG	2	1,836	425	NH												
35	NAM SANG	2	1,290	109	NH												
38	H.BANG BOT	2	2,402	462	KP												
39	NAM MI	2	1,032	83	NH												
47	NAM HINBOUN	2	2,529	421	AMR												
48	H.NAM HUAI	2	1,755	244	KP												
50	NAM HEUNG	2	4,901	1,106	LFB												
51	HUAI NAM SOM	2	1,072	152	LFB												
54	HUAI LUANG	2	4,090	830	LFB												
55	HUAI MONG	2	2,700	545	LFB												
57	NAM SUAI	2	1,247	277	LFB												
58	NAM LOEI	2	4,012	639	LFB												
64	NAM KAM	2	3,495	754	KP												
67	HUAI SOM PAK	2	2,516	584	AMR												
68	HUAI BANG SAI	2	1,367	255	KP												
70	HUAI BANG I	2	1,496	243	KP												
73	H.BANG KOI	2	3,313	658	KP												
75	SE BANG NOUAN	2	3,048	870	AMR												
76	HUAI KHAMOUAN	2	3,762	618	KP												
79	HUAI TOMO	2	2,611	615	BP												
80	TONLE REPON	2	2,379	309	KP												
85	O TALAS	2	1,448	254	NTS												
88	ST.CHIKRENG	2	2,714	778	NTS												
89	ST.SIEM REAP	2	3,619	892	NTS												
90	ST.STAUNG	2	4,357	1,070	NTS												
92	PREK PREAH	2	2,400	463	KM												
93	ST.SANGKER	2	2,344	530	CM												
94	ST.BATTAMBANG	2	3,708	1,207	CM												
95	TONLE SAP	2	2,744	325	TS												
96	PREK KRIENG	2	3,332	911	KM												
97	ST.DAUNTRI	2	3,696	891	CM												
99	PREK KAMP	2	1,142	309	KM												
100	PREK TE	2	4,364	1,189	VU												

10.3.3 Small tributaries

None of the small tributaries have high estimates of fish productivity, apart from B. Khai San in the Northern Highlands. This is also the only one making a significant contribution to the total productivity of Mekong tributaries. All others have medium levels of fish productivity, and a similar pattern can be seen with higher levels of productivity in the LFB and Khorat Plateau.

The high levels of productivity based upon consumption figures are evident for the H.Ma Hiao (Vientiane), Huai Khok, Nam Mang Ngai (Thakek), Huai Bang Haak (Nakhon Phanom).

The small tributaries that have medium fish productivity based upon water area are Doi Luang Pae Muang, Nam Thon, Hoaag Hua, Huai Muk and Prek Mun.

There are no real patterns to observe in the distribution of black and migratory fish in the small tributaries, and no correlation with floodplain and wetland areas.

Table 10-9: Comparing significant parameters to assess ecosystem productivity for small tributaries

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	**Physical Parameters**	Stream density	**Geological character**	Greatest proportions of Floodplains + wetlands	**Biodiversity and Fish**	Blackfish %	Migratory fish species %	Migratory/blackfish index	**Productivity**	Fish productivity (consumption)	Fish productivity (area of water body)
			sq km	km												
9	B.KHAI SAN	1	778	73	NH											
10	NAM KEUNG	1	633	52	NH											
13	DOI LUANG PAE MUAN	1	688	125	NH											
14	NAM NGAM	1	489	68	NH											
17	NAM MAE NGAO	1	485	69	NH											
30	NAM NHAH	1	316	63	NH											
33	MUANG LIEP	1	488	66	NH											
34	NAM TON	1	587	107	NH											
36	NAM THONG	1	455	129	NH											
37	NAM KADUN	1	456	83	AMR											
40	NAM PHONE	1	664	101	NH											
41	B.NAM SONG	1	138	4	NH											
43	H.SOPHAY	1	186	85	NH											
44	NAM THON	1	838	243	AMR											
45	PHU LUONG YOT HUAI	1	491	54	NH											
46	NAM KAI	1	602	71	NH											
49	H.MA HIAO	1	990	136	NH											
52	HOAAG HUA	1	626	131	AMR											
53	PHU PA HUAK	1	132	26	LFB											
56	H. KHOK	1	538	131	LFB											
61	NAM MANG NGAI	1	944	169	AMR											
62	HUAI THUAI	1	739	142	KP											
63	HUAI HO	1	691	136	KP											
65	HUAI BANG HAAK	1	938	159	KP											
69	HUAI MUK	1	792	145	KP											
78	HUAI BANG LIENG	1	695	206	BP											

10.4 Degree of modification

The degree of modification is illustrated by two complementary assessments of the least and greatest modifications. Least modification is assessed by identifying the tributaries with the lowest population density, the highest proportion of forested areas in the catchment, least land use modification, lowest road development, lowest irrigation percentage in the catchment, and lowest hydropower capacity. The last three are summarized in the tributaries with the lowest infrastructure index.

The tributaries with the greatest modification index and assessed through the highest population density, highest urban population percentage, highest urban area percentage of the catchment, highest paddy areas in the catchment and greatest landuse modification index. They are those with the highest road development, highest irrigation percentage and highest hydropower capacity. The last three are summarized in the tributaries with the highest infrastructure index.

10.4.1 Large tributaries

There is a clear grouping of the least modified large tributaries in the northern part of the LMB, as measured by population density, forested areas, lowest landuse modification, road development and irrigation. The tributaries with the lowest hydropower capacity are understandably those lower down in the LMB. Those with the highest forest areas in the catchment and lowest landuse changes include the Nam Tha, Nam Cadinh and Se Kong, but both the Nam Cadinh and Se Kong have high hydropower capacity.

Three tributaries stand out as having some significant least modified characteristics and no greatest modification characteristics. These are the Nam Tha, Nam Suong and Stung Sreng.

Nam Ou stands out as having a low population density, low landuse modification and low road and irrigation development, though it has a high urban population percentage and a high hydropower capacity. Nam Mae Kok has least landuse change, road development and hydropower development, but high urban populations and urban areas. Nam Khan has high forest, low roads, and irrigation development but high urban population percentage.

The Nam Chi and Nam Mun stand out because they have significant characteristics of greatest modification with none of the least modification characteristics. The Se Done has no highlights in the least modification characteristics and only an indicator of high urban populations percentage.

The Se San has high urban populations and high hydropower capacity and infrastructure index, but one of the least landuse change indices. The Sre Pok has a high infrastructure index and also a low landuse change index.

There is a grouping of the more southerly tributaries with high road development and low hydropower capacity (Siem Bok, Stung Chinit, Stung Pursat, Stung Baribo, Prek Chhlong, Delat and Prek Thnot). Of these Siem Bok, Prek Chhlong and the Delta has high irrigation development, and these three also have high infrastructure indices. The Delta emerges as one of the catchments with the greatest modification.

The Stung Chinit, Stung Pursat and Stung Baribo have least infrastructure indices, and only high road development, although the Stung Baribo also has high population densities and high urban population percentage.

Table 10-10: Comparing significant parameters to assess ecosystem modification for large tributaries

						Least Modification								Greatest Modification								
Code	Tributary	Size category	Catchment area	Stream length	Geological zone	Lowest Population density	Highest Forested areas in catchment	Least land use modification	Lowest road development	Lowest Irrigation %	Lowest KW/km	Infrastructure index		Highest Population density	Highest Urban population %	Highest Urban area %	Highest Paddy areas	Greatest Land use modification	Highest road development	Highest Irrigation %	Highest KW/km	Infrastructure index
			sq km	km																		
1	NAM OU	3	26,033	5,740	NH																	
3	NAM THA	3	8,918	1,029	NH																	
5	NAM MAE KOK	3	10,701	1,833	NH																	
6	NAM SUONG	3	6,578	1,070	NH																	
15	NAM KHAN	3	7,490	1,454	NH																	
16	NAM MAE ING	3	7,267	1,682	NH																	
24	NAM NGUM	3	16,906	3,365	NH																	
29	NAM CADINH	3	14,822	2,981	AMR																	
42	NAM SONGKHRAM	3	13,123	2,759	KP																	
59	SE BANG FAI	3	10,407	1,583	AMR																	
60	NAM CHI	3	49,133	9,303	KP																	
66	SE BANG HIENG	3	19,958	5,114	AMR																	
71	SE KONG	3	28,815	4,932	KM																	
72	NAM MUN	3	70,574	12,192	KP																	
74	SE DONE	3	7,229	2,249	AMR																	
77	SE SAN	3	18,888	2,785	KM																	
81	ST.SRENG	3	9,986	2,091	NTS																	
82	ST. SEN	3	16,360	3,182	NTS																	
83	ST.MONGKOL BOREY	3	14,966	3,171	NTS																	
86	SRE POK	3	30,942	6,729	KM																	
87	SIEM BOK	3	8,851	2,258	NTS																	
91	ST.CHINIT	3	8,237	1,748	NTS																	
98	ST.PURSAT	3	5,965	1,597	CM																	
101	ST.BARIBO	3	7,154	2,192	CM																	
102	PREK CHHLONG	3	5,957	1,713	VU																	
103	DELTA	3	48,235	5,467	D																	
104	PREK THNOT	3	6,124	1,740	CM																	

10.4.2 Medium tributaries

The medium tributaries appear to be least modified especially in the Northern Highlands and further south in terms of hydropower capacity. An exception to this is Nam Mae Kham which has high urban populations and urban areas and the greatest land use modifications. Nam Beng and Nam Ngeun has a high infrastructure index, and Nam Nhiep has both a high infrastructure index and high hydropower capacity. Nam Sane and Nam Mang have high hydropower capacity.

On the Khorat Plateau, Huai Bang Bot has high landuse change influenced by high paddy areas in the catchment. H. Nam Huai has high irrigation which raises its infrastructure index.

There is a grouping of catchments in the LFB with high populations, high urban percentages and urban areas, paddy areas and high landuse modification. These include Huai Luang, Huai Mong, Nam Suai. Nam Loei has a high landuse modification.

Nam Kam emerges as a medium tributary with greater modification as a result of high population density, high paddy areas, high irrigation and high infrastructure index.

Many of the tributaries of the Tonle Sap, have high infrastructure indices, but St. Siem Reap and St. Dauntri stand out because of high paddy areas and high road development, and St Siem Reap also has a high population density.

Table 10-11: Comparing significant parameters to assess ecosystem modification for medium tributaries

Code	Tributary	Size category	Catchment area (sq km)	Stream length (km)	Geological zone	Least Modification: Lowest Population density	Highest Forested areas in catchment	Least land use modification	Lowest road development	Lowest Irrigation %	Lowest KW/km	Infrastructure index		Greatest Modification: Highest Population density	Highest Urban population %	Highest Urban area %	Highest Paddy areas	Greatest Land use modification	Highest road development	Highest Irrigation %	Highest KW/km	Infrastructure index
2	NAM NUAO	2	2,287	259	NH																	
4	NAM MA	2	1,141	110	NH																	
7	NAM PHO	2	2,855	395	NH																	
8	NAM MAE KHAM	2	4,079	1,046	NH																	
11	NAM NGAOU	2	1,495	193	NH																	
12	NAM BENG	2	2,131	176	NH																	
18	NAM KHOP	2	1,521	345	NH																	
19	NAM TAM	2	1,548	217	NH																	
20	NAM NAGO	2	1,008	220	NH																	
21	NAM SING	2	2,681	438	NH																	
22	NAM PHUONG	2	4,139	417	NH																	
23	NAM NGEUN	2	1,819	323	NH																	
25	NAM HOUNG	2	2,872	556	NH																	
26	NAM NHIEP	2	4,577	707	NH																	
27	NAM PHOUL	2	2,095	348	NH																	
28	NAM SANE	2	2,226	443	NH																	
31	NAM NHIAM	2	1,990	265	NH																	
32	NAM MANG	2	1,836	425	NH																	
35	NAM SANG	2	1,290	109	NH																	
38	H.BANG BOT	2	2,402	462	KP																	
39	NAM MI	2	1,032	83	NH																	
47	NAM HINBOUN	2	2,529	421	AMR																	
48	H.NAM HUAI	2	1,755	244	KP																	
50	NAM HEUNG	2	4,901	1,106	LFB																	
51	HUAI NAM SOM	2	1,072	152	LFB																	
54	HUAI LUANG	2	4,090	830	LFB																	
55	HUAI MONG	2	2,700	545	LFB																	
57	NAM SUAI	2	1,247	277	LFB																	
58	NAM LOEI	2	4,012	639	LFB																	
64	NAM KAM	2	3,495	754	KP																	
67	HUAI SOM PAK	2	2,516	584	AMR																	
68	HUAI BANG SAI	2	1,367	255	KP																	
70	HUAI BANG I	2	1,496	243	KP																	
73	H.BANG KOI	2	3,313	658	KP																	
75	SE BANG NOUAN	2	3,048	870	AMR																	
76	HUAI KHAMOUAN	2	3,762	618	KP																	
79	HUAI TOMO	2	2,611	615	BP																	
80	TONLE REPON	2	2,379	309	KP																	
85	O TALAS	2	1,448	254	NTS																	
88	ST.CHIKRENG	2	2,714	778	NTS																	
89	ST.SIEM REAP	2	3,619	892	NTS																	
90	ST.STAUNG	2	4,357	1,070	NTS																	
92	PREK PREAH	2	2,400	463	KM																	
93	ST.SANGKER	2	2,344	530	CM																	
94	ST.BATTAMBANG	2	3,708	1,207	CM																	
95	TONLE SAP	2	2,744	325	TS																	
96	PREK KRIENG	2	3,332	911	KM																	
97	ST.DAUNTRI	2	3,696	891	CM																	
99	PREK KAMP	2	1,142	309	KM																	
100	PREK TE	2	4,364	1,189	VU																	

10.4.3 Small tributaries

There is a clear pattern amongst the small tributaries that those in the Northern Highlands are least modified, except for the Nam Ngam, which has high population density, urban areas (Houai Xai) and infrastructure index. H. Ma Hiao (Vientiane) also is one of the most highly modified small tributaries with high population density, urban population, urban area, paddy area, land use modification and road development.

From the Annamites, the Nam Kadun has high population density, road development, irrigation and infrastructure index. Also in the Annamites, Huaag Hua and Nam Mang Ngai appear to be highly modified by road development and irrigation. Nam Mang Ngai has high population densities, urban populations and area, and high land use modification and infrastructure index. The Nam Thon stands out amongst these Annamite tributaries as having least modification.

From the LFB and Khorat Plateau, the small tributaries are heavily modified including Phu Pa Huak, H. Khok, Huai Thuai, Huai Ho, Huai Bang Hak and Huai Muk. These are modified by high population densities, high paddy areas and high land use modification. They have no hydropower capacity.

The Huai Bang Lieng from the Bolevan and Prek Mun stand out amongst the lower small tributaries with less modification although Prek Mun has a high land use modification.

Table 10-12: Comparing significant parameters to assess ecosystem modification for small tributaries

						Least Modification								Greatest Modification								
Code	Tributary	Size category	Catchment area	Stream length	Geological zone	Lowest Population density	Highest Forested areas in catchment	Least land use modification	Lowest road development	Lowest Irrigation %	Lowest KW/km	Low Infrastructure index		Highest Population density	Highest Urban population %	Highest Urban area %	Highest Paddy areas	Greatest Land use modification	Highest road development	Highest Irrigation %	Highest KW/km	High Infrastructure index
			sq km	km																		
9	B.KHAI SAN	1	778	73	NH																	
10	NAM KEUNG	1	633	52	NH																	
13	DOI LUANG PAE MUAN	1	688	125	NH																	
14	NAM NGAM	1	489	68	NH																	
17	NAM MAE NGAO	1	485	69	NH																	
30	NAM NHAH	1	316	63	NH																	
33	MUANG LIEP	1	488	66	NH																	
34	NAM TON	1	587	107	NH																	
36	NAM THONG	1	455	129	NH																	
37	NAM KADUN	1	456	83	AMR																	
40	NAM PHONE	1	664	101	NH																	
41	B.NAM SONG	1	138	4	NH																	
43	H.SOPHAY	1	186	85	NH																	
44	NAM THON	1	838	243	AMR																	
45	PHU LUONG YOT HUAI	1	491	54	NH																	
46	NAM KAI	1	602	71	NH																	
49	H.MA HIAO	1	990	136	NH																	
52	HOAAG HUA	1	626	131	AMR																	
53	PHU PA HUAK	1	132	26	LFB																	
56	H. KHOK	1	538	131	LFB																	
61	NAM MANG NGAI	1	944	169	AMR																	
62	HUAI THUAI	1	739	142	KP																	
63	HUAI HO	1	691	136	KP																	
65	HUAI BANG HAAK	1	938	159	KP																	
69	HUAI MUK	1	792	145	KP																	
78	HUAI BANG LIENG	1	695	206	BP																	
84	PREK MUN	1	476	121	KP																	